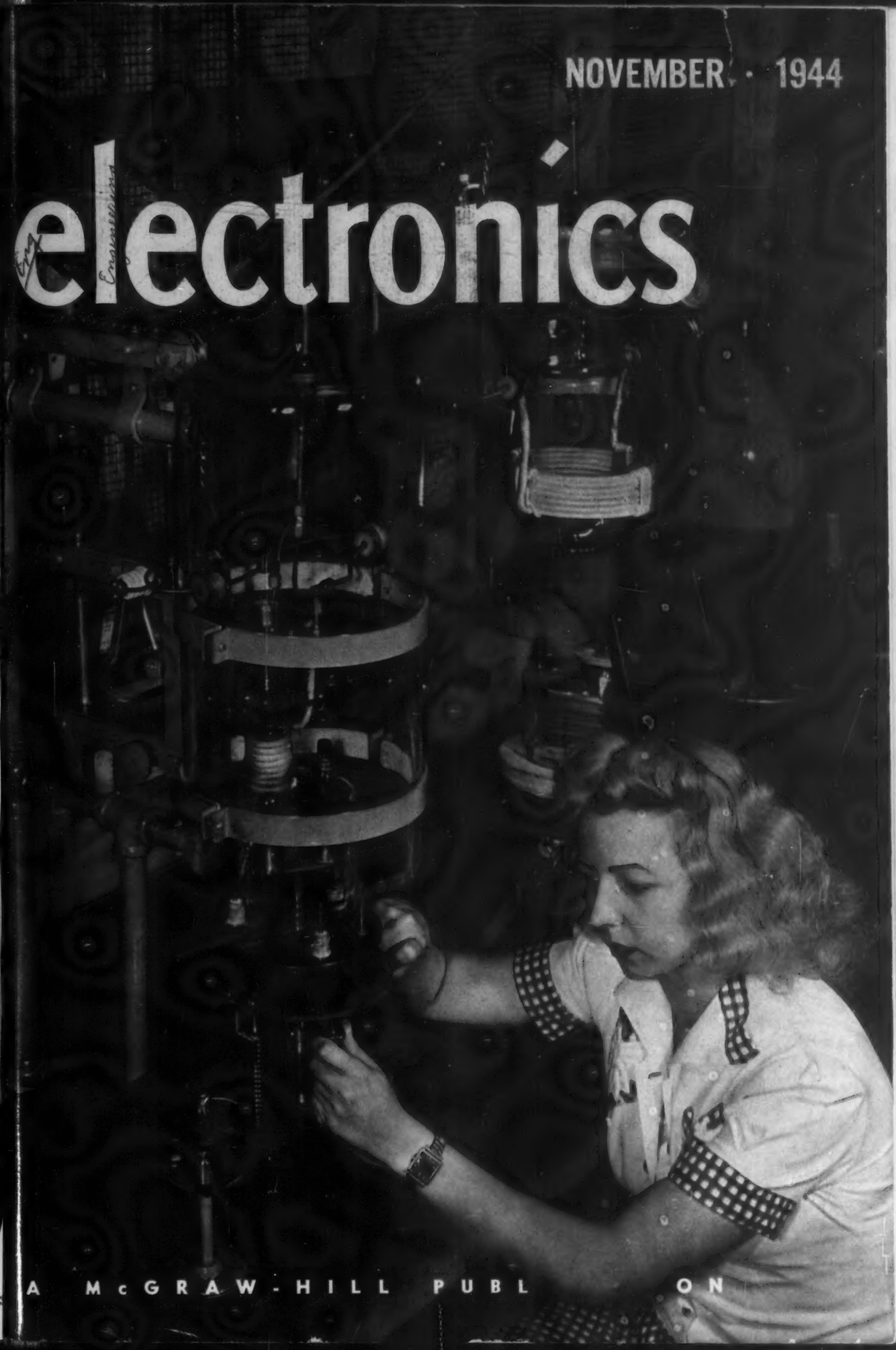
NOVEMBER · 1944

electronics



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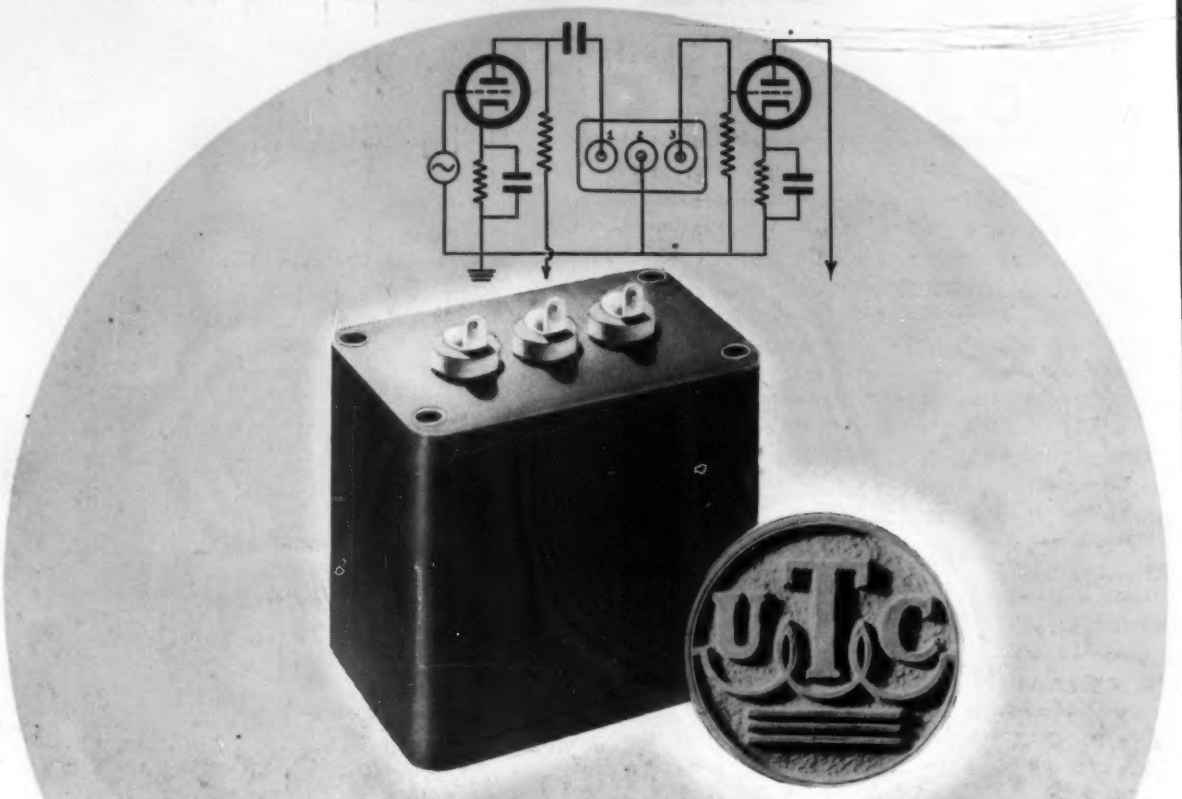
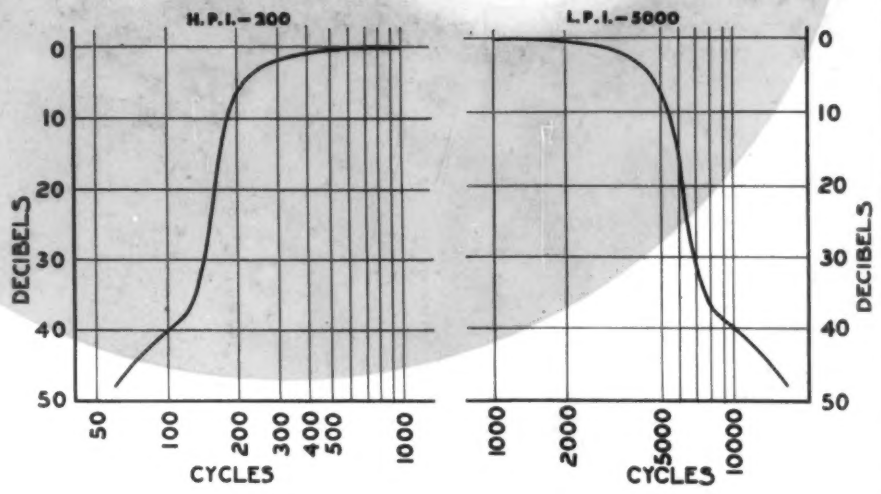
LOW PASS (TYPE L.P.I.)
HIGH PASS (TYPE H.P.I.) FILTERS





New additions to the UTC Interstage Filter family are now available in the type HPI and LPI units, respectively high pass interstage and low pass interstage filters.

The units are designed with a nominal impedance of 10,000 ohms to be used in a circuit as illustrated. Typical curves obtainable are shown above. Loss at cutoff frequency is less than 6 DB. At .75 times cutoff or 1.5 cutoff frequency respectively, the attenuation is 35 DB, and at one-half or twice cutoff frequency respectively, the attenuation is 40 DB.

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Director of Circulation:
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To.....

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Signed.....

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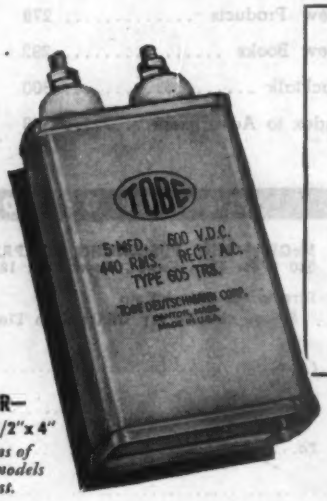
LONG, UNINTERRUPTED service under all operating conditions is the characteristic you want most in a capacitor. Tobe Capacitors serve so well and so long because every step in their manufacture is checked and cross-checked by rigid inspections. Constant improvement through constant research is the promise performed by Tobe engineers. An example is the Tobe TRS Capacitor, shown below, a skillfully designed transmitting condenser. Why not call on Tobe for prompt, specialized help on *all* your capacitor problems?



TRS 605,
5 mfd. 600 volts
SIZE—
Overall height 5″
CONTAINER—
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Dimensions of other TRS models on request.

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Capacitor unit tested at 2 times rated voltage.

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A small part in Victory today . . .

A BIG PART IN INDUSTRY TOMORROW

RUSSIA

Threat . . . or Promise?

WHEN this war is ended, two nations—the United States and Russia—will possess the bulk of the world's military and industrial might.

Whether this new situation will hold seeds of catastrophe or of unprecedented opportunity will be determined by policies . . . still to be formulated.

If this concentration of power leads to a bitter struggle for supremacy, then the world will be turned into a giant munitions factory.

If it is used cooperatively to maintain order, then, I believe, the stage is set for a long era of prosperity . . . and peace.

It is time that Americans, whether of the Right or the Left, face this basic issue squarely and open-mindedly.

☆ ☆ ☆

No group in this country has a greater stake than have business and industry in seeing that a satisfactory Russian-American understanding is reached.

Without such an understanding there can be no reasonable hope for more than a temporary and insignificant reduction of our crushing wartime tax burden. If the threat of a clash between these two giants impends, neither bankers nor governments will run the risk of lending on a scale adequate to maintain international trade at levels necessary for our future prosperity. Potential international customers, instead of buying freely in open world markets, will be forced—as during the dangerous period introduced by Hitler in the early 1930's—into the trading camp of whichever power they fear most.

If, however, Moscow and Washington will agree on cooperative plans for maintaining the peace, American business will enjoy enormous new trade opportunities after the war.

☆ ☆ ☆

Russia, during the three and one-half years since it was attacked by Hitler, has conclusively proved to a doubting world that it is a top-flight military power.

Soviet railroads did not break down under the strain of war.

Regions accounting for nearly 70 per cent of Stalin's key industries were engulfed by the invading Nazis, but before they fell, Soviet management engineers performed a near miracle by transplanting entire industries a thousand miles to the Urals with the loss of as little as four months' production in many cases.

Though American planes, trucks, and medical supplies have been welcomed by Moscow, fairness demands the admission that more than 98 per cent of American production has *not* gone to the Russian front.

Russian planning and *Russian* equipment won the victories of Leningrad, Stalingrad, and the Caucasus.

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But these measures of Soviet military strength—indicative as they are of an unsuspected economic development—fail to picture in adequate detail the startling potential of the Russian market after the war.

Russia, for instance, has two and one-half times the area of the United States.

It has a population of nearly 200,000,000, and this is increasing at the rate of 2,500,000 a year.

And statistics just released show that Russia has three times as many youngsters under 16 as has the United States. This is a measure both of war potential and of a vast commercial market.

And remember that in no part of the world before the war was per capita production rising as rapidly as in the Soviet Union.

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German armies occupied a region in Russia roughly equivalent to the territory in the United States north of Richmond, Virginia, and east of the Mississippi.

This huge area—with its counterparts of Pittsburgh, Buffalo, and Bridgeport; of Illinois corn fields, New York dairy farms, and Maine potato harvests—was *twice* subjected to the most withering destruction; first by the Russians themselves when they retreated before the Germans, and then by the Germans when they withdrew before the victorious Russians.

As a result, 30,000,000 people are in urgent need of complete reoutfitting. They need houses and shoe laces, trolley cars and baby carriages, tractors and livestock, hydroelectric plants and electric light bulbs.

Many of these needs will be met at home. It is doubtful, for instance, if Moscow will import cooking utensils or sewing machines, for many of Russia's huge war factories can quickly be converted to peacetime production of such consumer goods.

But for the rebuilding and expansion of her industries Russia looks to the United States for equipment.

Soviet representatives already are in this country with authority to negotiate for technical men and the equipment necessary to rebuild the great Donbas coal mines according to the most modern American methods.

It is important to remember that Russia's whole iron and steel industry, its non-ferrous mining and processing, some of its chemical production, much of its coke roasting and gas recovery, practically its entire automobile and tractor industry, and the largest of its hydroelectric plants, are based on American machinery and processes.

It is known among manufacturers that Russia recently has asked for bids on shipbuilding equipment, construction and roadbuilding machinery, alloy steels, textile machines, plastics, and a long list of rail, air, and water transport supplies.

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The Soviet Union, however, has more than a rehabilitation job on its drawing boards.

The first Five-Year Plan, which, as we all remember, was completed ahead of time in 1932, was devoted almost exclusively to heavy industry. Russia set out to build for itself the machines and the factories which, in later years, could turn out, at home, modern equipment for a vast range of light industries.

Stalin, when he inaugurated the second of his famous Five-Year Plans, promised that before it was completed Soviet factories would begin to turn out a flow of con-

sumer goods—ready-made dresses, canned foods, soap, cosmetics, shoes, kitchenware, automobiles, telephones, and modern houses.

But, by 1935, Moscow realized that Russia could not afford to enjoy such luxuries in the face of growing political tension in Europe. So, when the third Five-Year Plan was launched, there was no fanfare. Russians continued to wear their old clothes, to eat whatever simple food was available, and began grimly to build the industries which ultimately produced enough tanks, planes, and guns to turn the tide of battle at Stalingrad.

It is characteristic of Moscow that even before the last battles with the Nazis are over, Russia is planning to pick up its Five-Year Plans where the war had interrupted them.

Invitations to participate in a permanent exhibition in Moscow already have been mailed to American manufacturers. Soviet officials want their public to see samples of our new machine tools, aluminum and alloy products, oil-drilling machinery, bulldozers, and prefabricated kitchen equipment. Russia already is projecting specific plans to resume the job (1) of making the country an industrial giant comparable to the United States, and (2) of making life more pleasant for a long-suffering people.

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What is the measure of this postwar market in the Soviet Union?

Some estimates place the total quantity of goods which Russia might take from the United States during the first two or three years after the war as high as $5,000,000,000 a year. Then, as Russian industry is restored, imports from the United States might taper off perhaps to $2,000,000,000 a year.

Actually, these estimates are far too optimistic, unless the United States is prepared (1) to help Russia pay by buying vast quantities of Soviet raw materials, and (2) to provide large credits to handle the purchases during the first few years of rehabilitation.

The relations of American exporters with Russia during the period covered by the three Five-Year Plans have been eminently satisfactory. Moscow has met all of its obligations punctually; fifteen years of experience have reduced contract forms to the point where they cause a minimum of misunderstanding between the Russian representatives and the American producers; individual American companies with extensive prewar experience in handling Soviet business already are offering large credits on initial postwar orders though these may yet be replaced by large government credits at lower interest rates.

But the volume of trade with Russia after the war hinges upon Moscow's ability to pay. Never before the war did the United States buy more than $30,000,000 of goods a year from Russia. As late as 1938, Soviet exports to this country amounted to as little as $23,500,000, far less than enough to pay even the service charges on the credits which would have to be extended in connection with exports of several billion dollars a year. Only South Africa produces more new gold each year than the Soviet Union. But the United States does not want gold; more of it would only complicate the problem of controlling prices here.

If the United States, however, is to achieve, after the war, the high level of national income which is necessary (1) to keep our expanded factories in operation, and (2) to service the national debt, it might absorb from $90,000,000 to $100,000,000 a year of the kind of goods bought from Russia before the war—furs, timber, manganese, chromium, and handicrafts. But unless this volume of purchases from Russia can be boosted by another $50,000,000 annually, credits of the size necessary to fill immediate Russian needs could not be serviced without large supplemental importations of undesirable gold.

The nub of the situation is that Russia offers an extraordinary potential market particularly for our heavy industries which have grown so enormously during the war. But if this sales outlet is to materialize, then the United States must find a way to import from Russia (or from Russia's debtors if any) from ten to twenty times as much as we did before the war. Instead of merely going after the export business, American businessmen must explore with the Russians the possibility of buying bigger supplies of Soviet products.

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But more than the Russian market itself hinges upon sound cooperative action by the world's two leading military-industrial nations.

If trade between them is held to a minimum and if relations are strained, the flow of trade all over the world will be adversely affected.

Europe, long this country's biggest export outlet, certainly will never take the bold steps necessary to reconstitute its economy on a peacetime basis if Russia and the United States drift into a race for military supremacy.

The Balkan states, which may be industrialized by Moscow in order to reduce their dependence on Germany, and the Arab world with its huge need for transportation, irrigation, and sanitation, will not dare accept American credits or make big contracts with American engineers if Moscow frowns on the deals.

And refusal of Russia and the United States to work cooperatively to maintain the peace would kill, in their present embryonic stage, all dreams of a vast industrialization program for China.

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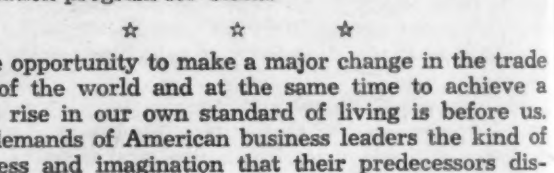
The opportunity to make a major change in the trade map of the world and at the same time to achieve a sharp rise in our own standard of living is before us.

It demands of American business leaders the kind of boldness and imagination that their predecessors displayed when they pioneered this country's unknown West.

It demands realistic action by men who know that the solution to this country's *real* foreign trade problem under today's conditions lies in boosting *imports* not exports alone . . . men who are not afraid of being paid for what they sell.

It calls for leaders who will approach Moscow and other major customers at once with constructive plans that would parallel in scope those on which this country is waging war . . . leaders who will make it clear at the outset that this bid for cooperative action emphatically demands that each nation shall have complete freedom to determine its internal political and economic organization without interference from the other.

It is *this* caliber of leadership upon which our future hinges.



President McGraw-Hill Publishing Company, Inc.

THIS IS THE 29TH OF A SERIES

CROSS TALK

▶**SHARE . . .** From a service man in the South comes the plea: "I am seeing so much that is electronic in my work that I wish to supplement my work with reading in this field. I wonder if some of your readers who do not file their copies could forward them to me after they are through? In this manner they will help keep another soldier boy's intellect alert."

Seems like a marvelous idea. Anyone want Pvt. So-and-So's real name?

▶**ADJUSTMENT . . .** Not all of the adjustments, post-war, are going to be made by industry nor by returning service men. Many of the adjustments will have to be made by men who have stayed at home, making their contribution in any one of a dozen ways which have very little in common with their jobs before the war.

Consider the college professor, perhaps from a small and not too rich institution, who will be constantly surrounded by youngsters taking his courses because the curriculum requires it; always wishing for more apparatus than his department budget will tolerate, apparatus not only for demonstration but for some of his own research.

During the war he has been surrounded by colleagues whose intellectual background and interests and scientific attainments may not only equal his own but may even surpass them so that he learns while working; whose every request for research equipment is quickly gratified.

Or, consider a small-company engineer or scientist who will have limited funds for research, with a small staff, under the constant necessity of producing profitable items, never quite free to work on his own ideas because they are not right down the company line.

During the war he has unlimited funds, his staff may be numbered in the scores of hundreds, and his sole aim is to produce devices the success of which is gaged solely by their excellence for the job.

Colleges and industry must be cognizant of the emotional problems of such men when they return to our humdrum world; must remember that their returning personnel may have had visions which cannot possibly be duplicated on the home grounds. Somehow, means must be found to condition favorably the atmosphere in which these war-time contributors do their peace-time work.

▶**MAKEUP . . .** In all businesses there are exigencies; unexpected things that crop up to plague an otherwise pleasant setup. In the publishing business, one of the exigencies is the article that is a column or two too long to fit into the allotted space. One way out of the difficulty is to "turn-over" the extra column or two into the rear of the book.

ELECTRONICS readers are particularly busy at this time and should not have to paw through the rear of the book to read the end of any technical article. Beginning in this issue, the editors intend to make articles "break even" up front, to end them in the feature section where they start if this is humanly possible. Only in makeup emergencies and to avoid emasculating material will they diverge from this new policy.

▶**FIRE . . .** It seems to be a normal male desire to chase fires. Well, out in Ohio several electronic engineers enjoyed this pastime so much they got busy and developed a whole fire alarm system for their particular town, presented it to the town and had themselves cut in on the circuits so they could really chase fires efficiently!

INTERNATIONAL Radio Frequency Proposals

Preparing for forthcoming Treaty Conferences, a committee of industry and government representatives is currently meeting under the sponsorship of the State Department. Its work is far from completed but some of the initial suggestions do point toward things to come

INTERNATIONAL ASPECTS of the radio art are attracting the close attention of post-war planners in a series of meetings currently being held in Washington.

The State Department, which is charged with the preparation of proposals for international treaties in the telecommunications field, has undertaken to obtain the advice and guidance of other government departments and the industry, looking toward the next Treaty Conference at which existing international law and regulations will be revised to meet new technical and economic conditions. Such a revision is long overdue.

Major Committee Objectives

The present international radio law rests in the International Telecommunications Convention formulated at Madrid in 1932, and the General Radio Regulations as revised at the Cairo Conference in 1938.

Since 1938, much water has gone over the dam. New regions of the ether spectrum have been opened to extensive use. Existing allocations and services have assumed new relative positions of importance. The interference problem, due in part to disregard of international service assignments, has become so acute that it borders on the chaotic. The war has brought with it many new developments in aviation and long-distance communication, many of which will continue in peacetime.

Many of the aspects of the work now in progress are legal in nature, particularly the delicate questions of the sovereign rights of nations and the enforcement of treaty agreements. But an equally large part of the work is technical, and it is this task which has been assigned to a committee under the chairmanship of Dr. J. H. Dellinger.

The committee consists of members from industry, including many active in the Radio Technical Planning Board, and from government departments including the Army, Navy, and the FCC. The meetings began August 11 and 12, were resumed on September 20 and 21, and later meetings are scheduled to follow the Allocation Hearings of the FCC which began on September 28.

The Technical Committee has been charged with two main investigations: (1) A general survey of the definitions and standards which should govern international allocation and standardization of frequency assignments, and (2) a specific study of frequency allocations to particular services.

The work has by no means been completed, so it is not possible to report official conclusions. But at the initial meeting, representatives of the State Department stated that the proceedings might be reported in the press as they proceeded provided that no direct quotations were made from the draft proposals and minutes.

Definitions and Standards

The first portion of the work of the technical committee, relating to definitions and standards, is concerned with proposed changes in the Radio Regulations (Cairo, 1938). Changes may be extensive.

It is evident that the introduction of frequency modulation has changed concepts in a number of particulars. It is proposed, for example, to classify the emission of a transmitter as "A" for amplitude modulation, "F" for frequency modulation (and phase modulation) or "AF" for emissions combining the two types. Following this designation is a number which denotes the bandwidth occupied by the transmissions, expressed in kilocycles. Thus a standard broadcast station would bear the designation A10, and a standard frequency modulation station F150. (The symbol "T" has also been suggested for keyed signals.)

The methods of calculating the bandwidth of given classes of station are stated in the proposed regulations as follows: A pure cw telegraph station has a bandwidth in kc equal to 0.0005 BW, where B is the average bauds per letter (a number ranging from 5.0 for a five-unit teleprinter signal to 8.4 for international Morse code), and W is the number of words per minute transmitted. The bandwidth of a modulated cw telegraph station is equal to the above expression, plus twice the modulation frequency. An amplitude-modulated station (voice or music) has a bandwidth equal to twice the modulating frequency. A frequency-modulated station (voice or music) has a bandwidth of twice the maximum frequency swing, in kc, provided the swing is equal to or greater than the highest modulating frequency,

which it is in nearly all practical cases.

To assist in comparing various transmissions on an equal footing it is proposed to rate transmitters in terms of the peak power supplied to the antenna in normal operation.

Emissions outside the authorized bandwidth must be at least 26 db below the maximum radiated field within the authorized band, and if interference is caused by such "extra-band" emissions they must be further reduced.

Only two types of services are defined, "fixed" and "mobile." A portable station assumes the classification of the service in which it operates, even if such operation is on a temporary basis. Thus a portable station temporarily operating from a specified fixed location is a fixed station. If used while in motion, or at unspecified fixed locations en route, it is a mobile station.

It is proposed that in the future, station assignments be specified in frequency, in kilocycles or megacycles, and not in terms of wavelength.

Specific limits to the permissible amount of radiation on harmonics of the assigned frequency are proposed; the peak power of the radiated harmonic is to be 40 db below the peak power of the fundamental, and in no event greater than 200 milliwatts.

It is proposed that the use of damped radio-frequency oscillations be specifically forbidden.

Proposed Table of Allocations

The proposal most of interest to the readers of ELECTRONICS is the Frequency Allocation Table. This table is in no sense in final form, and was offered to the Committee primarily as a means of "starting the argument."

The table was drawn up by the Inter-Department Radio Advisory Committee (IRAC), the official government committee on radio allocations. The proposed table may be viewed as a preliminary statement of the government interest in frequency allocations. The interest of the industry, in contrast, is being formulated by the Radio Technical Planning Board, and its recommendations have been separately presented before the Allocations Hearings of the FCC.

The IRAC set up the various radio services in general order of priority as follows: (1) Services concerned with the preservation of life and property, particularly navigation aids and distress calling service, (2) communication services of an essential nature which cannot be supplied by non-radio means, such as maritime and aeronautical communications not covered in the first classification, (3) broadcasting, including standard, fm, television and facsimile, (4) communication services using radio because the use of wire lines is not expedient, such as transoceanic telegraph and telephone, and (5) other radio services.

Amateurs Well-Protected

A most important aspect of the table is the extent of the spectrum covered, from the lowest frequencies, about 10 kc, to an upper limit at 30,000,000 kc (30,000 Mc, or 1-centimeter wave length).

The highest specific service proposed is a band from 21,000 to 22,000 Mc for amateur service. The amateur bands, which are of outstanding interest to an industry composed largely of amateurs and ex-amateurs, are proposed as follows: 3500-3900 kc, 7000-7400 kc, 14,000-14,400 kc, 21,000-22,000 kc, 28,000-30,000 kc, 144-149 Mc, 218-225 Mc, 420-460 Mc, 1125-1225 Mc, 2500-2700 Mc, 5200-5750 Mc, 10,000-10,500 Mc, ad 21,000-22,000 Mc, The pre-war bands at 15 meters and 5 meters are deleted, and a new band at 15 meters is proposed, as well as six new bands at wavelengths less than one meter.

No provision is made for international high-frequency broadcasting in the IRAC Table. This omission has caused considerable opposition on the part of the industry representatives, who feel that space must be found for this activity.

FM and Television Proposals

Frequency modulation and television receive an unbroken assignment from 42 to 108 Mc, divided in two regions, 42 to 54 Mc for fm, and 54 to 108 Mc for television. This proposal conflicts with that of the RTPB Television Panel which recommends assignments of six-megacycle channels from 50 to 246 Mc, excluding the 56-60 Mc region. The RTPB Panel on v-h-f Broadcasting recommends the region from approximately 40 Mc to approximately 56 or 60 Mc for fm.

The IRAC Table also makes provision for television on higher frequences, presumably with wider bandwidths than the 6 Mc currently used. These television assignments lie in the bands 460–508 Mc and 524–956 Mc.

Standard Broadcasting and Aviation

In the standard broadcasting band it is proposed to add one additional 10-kc channel at 540 kc.

Standard frequency broadcasting (of the WWV type) is proposed for international standardization at 2500 kc, 5000 kc, 10,000 kc, 15,000 kc and 20,000 kc.

Aviation radio in all its forms occupies a large place in the Table, as indeed it must in any post-war plan. It is proposed that all purely domestic aviation traffic control, airport communication and plane-to-plane and plane-to-ground communication be carried out on the u-h-f bands where no interference will be caused.

Navigation and Safety Devices

It may be wondered why the region of the spectrum above 30 Mc should be allocated definitely in an international agreement, since direct interference between nations on such frequencies is restricted to over-the-border cases, which could be solved by regional agreements within continental areas.

This fact is generally admitted. But it is equally evident that the maritime and aeronautical mobile services will employ v-h-f and u-h-f equipment for traffic control, instrument landing, harbor approach, navigation, collision prevention, and the like. Such "common carriers" engaged in international trade must be able to use the same equipment in any harbor or airport in the world.

Whether or not the proposed Table will remain in its present form when the Treaty Conference meets depends on the action taken by the State Department Committee, as well as on such action as the FCC may take following the presentation of the RTPB proposals.

for Land Navigation

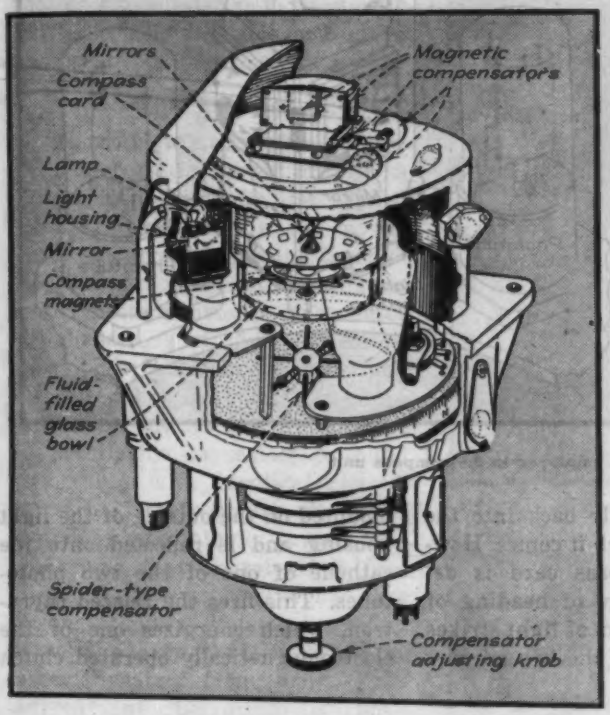
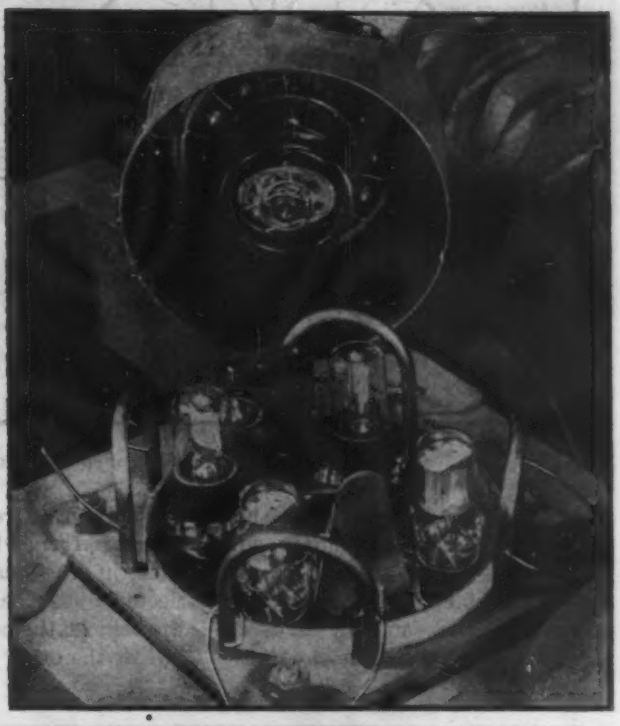


FIG. 2—Cutaway drawing of magnetic compass unit, which also contains the phototubes and thyratrons with their associated light source and deflecting mirrors



Lifting of compass bowl assembly exposes phototube-thyratron follow-up system that transfers compass indications to the plotting unit

functions of the odograph are often combined by using either the same or different instruments. Thus, maps made by one or more odographs can be used by other odograph-equipped vehicles. The unit is particularly valuable at night when guiding landmarks are not readily visible.

Some of the more important uses of the odograph may include tactical reconnaissance by armored and cavalry forces, navigation in unmarked terrain, rendezvous of units by various forces, surveys by field artillery forces, and reconnaissance and mapping by engineer forces.

The word odograph comes from the Greek, and literally means "writes the way" ("hodos" means "way" and "graph" means "write").

General Description of Installation

The installation involves three component parts: (1) A magnetic compass with its electronic conversion system; (2) A plotting unit with its 8½ by 11-inch map table, tracing pencil and mileage dials; (3) A power pack operating from the vehicle storage battery. Interconnections but not positions of these units are shown in Fig. 1; when installed, the plotting unit is positioned for accessibility and the compass for good magnetic conditions.

The plotting unit is actuated by the vehicle speedometer drive. The azimuth indication of the compass is transmitted to the plotting unit through the electronic control circuit. The total distance traveled and the proper directions are combined in the plotting unit to give a record of the course. A magnetic compass is used because of the relative complexity and size of a complete self-directing or north-seeking gyroscopic compass, and because the shock and rapid changes in direction involved in land operation are too severe for such an apparatus.

Details of the Compass

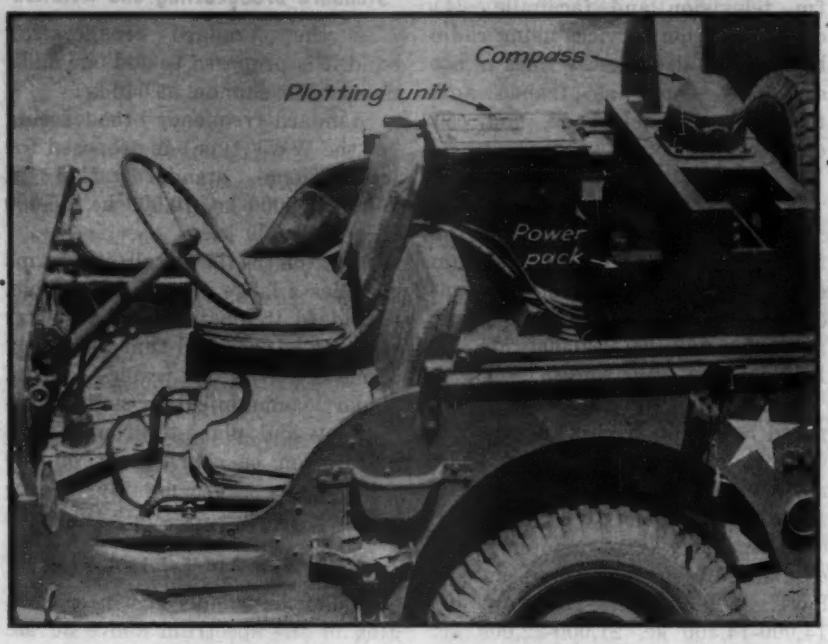
In order to plot a course, both the distance traversed and the direction must be known. Direction sensing in the odograph is accomplished by the compass, which has for its basic element a magnetic card assembly inclosed in a glass bowl, as illustrated in Fig. 2. The bowl is filled with a petroleum fluid which exerts a retarding influence on fins which project downward into it from the compass card proper. This gives damping to prevent erratic motion.

Mounted at the center of the card are two mirrors which are assembled at a dihedral angle having a horizontal axis as shown in Fig. 2. Response of the magnetic card to the influence of the earth's magnetic poles causes the card mirrors to face in a northerly direction immediately following any displacement of the compass housing.

The rest of the compass unit is related to the card only by optical means. A focused beam of light shines through the glass bowl onto the center point of the compass-card mirrors and is reflected back toward mirrors on the outside of the light housing, as shown in Fig. 3. The housing and the phototubes and thyratrons are mounted on a revolv-

Automatic Map Tracer

The odograph, now in production for installation in jeeps, utilizes phototubes and thyratrons to transfer the indications of a precision magnetic compass to a plotting unit actuated by a speedometer drive cable, causing a pencil to trace on an appropriate map the exact course taken on roads or on cross-country movements



Land odograph, M-1, installed in a ¼-ton Army truck for road reconnaissance. Installations in this type of vehicle have given the most satisfactory performance so far because the compass can be mounted away from large magnetic masses

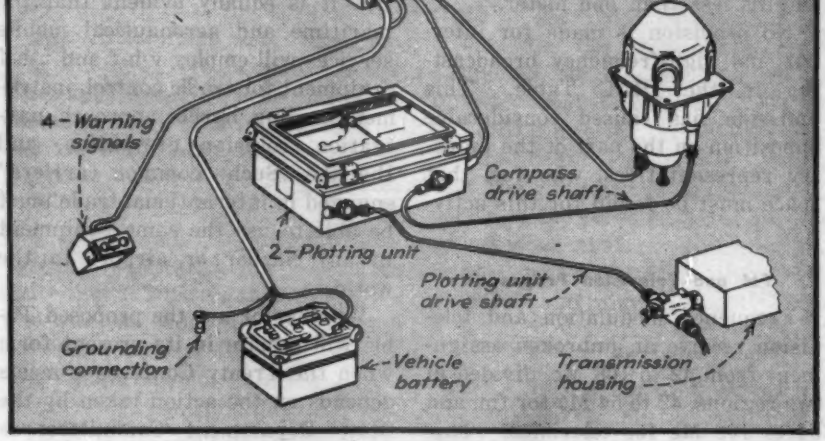


FIG. 1—Interconnection of units in an odograph installation. One warning signal blinks continually while the instrument is in operation. The other signal lamp flashes when the tracing pen is about to go off the map table, indicating that the vehicle is moving out of the area covered by the map being used

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IN military use the Odograph, Land, M-1 is installed in ¼-ton trucks (jeeps), to achieve two basic purposes: (1) Map making, or plotting the positions of objectives relative to a given base; (2) Navigation, or finding objectives whose position relative to a given base is known. These two functions are often combined.

Since the odograph automatically plots the course taken by a moving vehicle, unknown terrain is readily mapped by driving over it. In addition to obtaining maps of the roads, it is possible to plot locations of important points or objects either by driving the vehicle to the point, or estimating its distance and azimuth from a known location of the vehicle with a range finder. In transport or reconnaissance, a map having the desired course can be placed directly on the odograph map table and the trace formed by the plotting pencil can be watched to make sure the correct route is being followed.

When travelling to a given objective whose position is known relative to the starting point, it is possible to plot the objective on the odograph map table and then drive the vehicle in the general direction of the objective by following roads or other convenient routes. Since at any given time the relative locations of the objective and the vehicle are always shown on the odograph map, the vehicle can reach the objective even though the driver has no previous knowledge of the road net and terrain.

Mapmaking and navigational

yokes in the plotting unit and thereby causes the driving motor in that unit to rotate the flexible shaft until the compass table is back in alignment with the compass card.

Functioning of Electronic Circuit

The complete electronic circuit of the odograph is shown in Fig. 4. When plate voltage is first applied to the thyratrons by the power pack, no current is flowing through the 200-ohm rheostat serving as cathode bias resistance, and one of the thyratrons will fire. (Theoretically, both tubes should fire simultaneously, but in practice one tube will nearly always fire first since it is practically impossible to build two tubes with identical characteristics. If both do fire, the power switch is momentarily turned off.)

Assume that thyratron *B* fires first. It permits current flow through the bias resistor, providing a voltage drop that prevents the other thyratron from firing. Plate current of thyratron *B* flows through clutch electromagnet *C*, actuating the clutch and causing the plotting-unit motor to rotate the compass table in one direction. At the same time, the 1.0-μf capacitor connected between the thyratron plates becomes charged to approximately 185 volts.

Rotation of the compass table in the direction associated with clutch *C* soon results in light being reflected from the compass card mirror onto phototube *D*, which controls nonconducting thyratron *E*. This light reduces the resistance of the phototube, allowing current to flow through the 5-Megohm resistor in the grid circuit of thyratron *E* in such a direction as to make the grid of *E* positive with respect to its cathode. As a result, this tube fires, and its plate-cathode voltage drops from 200 volts to 15 volts. For an instant both thyratrons are conducting, but the plate-to-plate capacitor discharges, placing a negative voltage of minus 170 volts on the plate of thyratron *B* long enough to block this tube and enable its grid to gain control.

Now thyratron *E* sends plate current through clutch *F*, causing the compass table to rotate in the opposite direction. Rotation continues until the light beam has swung over onto phototube *A*, triggering off thyratron *B* and thereby starting a new hunting cycle. This hunting action goes on continually while the odograph is in use, and circuit adjustments are normally such as to give a 5-degree hunt on each side of the compass course at a rate of approximately 100 to 115 complete cycles per minute.

The hunting action eliminates back-lash in the flexible shaft and associated gearing, and is also valuable in connection with the design of the plotting unit.

Sensitivity of the thyratrons is controlled by adjusting the 200-ohm bias rheostat. Since a tube will fire on zero grid bias, if the resistance of the bias rheostat is entirely out of the circuit the tube will fire regardless of the signal from the phototube.

At the other extreme, if the entire 200 ohms is in the cathode circuit, the thyratron will never fire. In practice, a setting is used between these two extremes or at about 120 ohms. A lower resistance than this will tend to speed up the hunting cycles of the apparatus and reduce the angle of hunt, while higher resistance will have the opposite effect.

So that the operator of the vehicle can observe the operation of the unit, a signal box is located on the dashboard. It contains a ¼-watt neon lamp which, in normal operation, glows on alternate electrodes in synchronism with the hunting

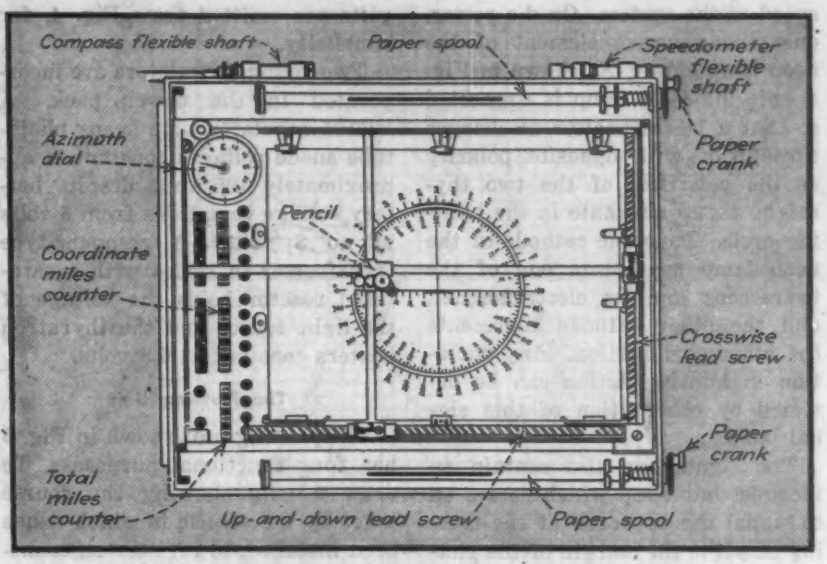
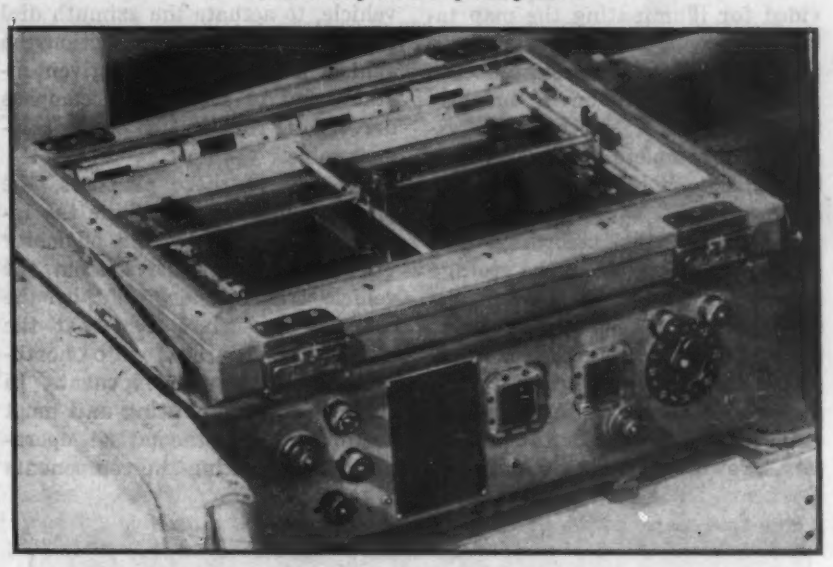


FIG. 5—Top view of plotting unit



Closeup of plotting unit with glass cover in place. A stubby automatic pencil is moved over the map table by the lead screws

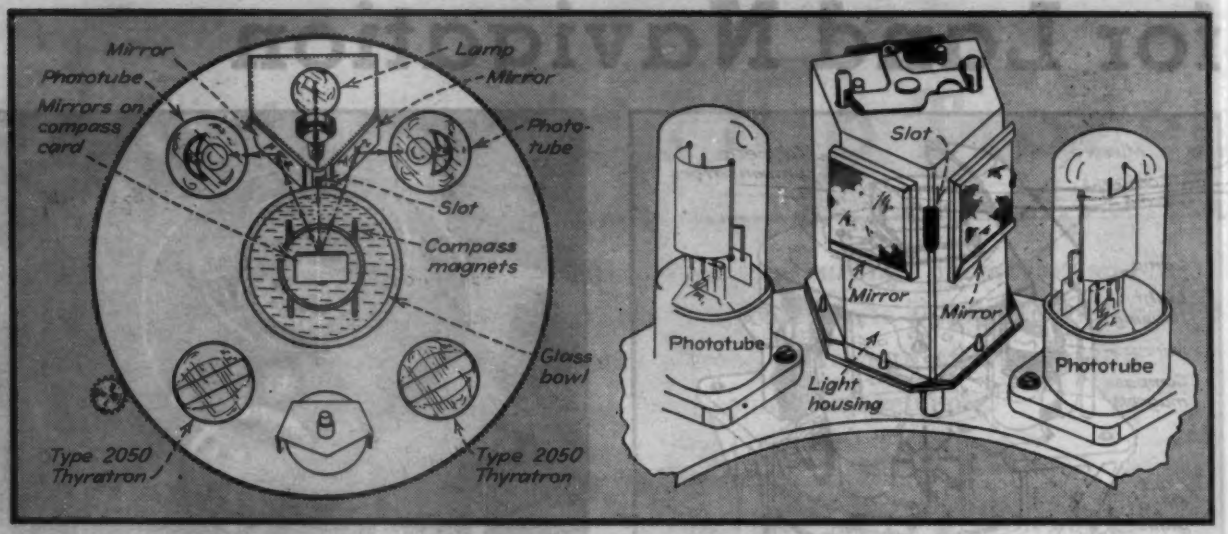


FIG. 3—Details of optical system employed in the compass unit

ing table geared to a flexible shaft which connects the compass with the plotting unit.

If this table is in correct alignment with the compass card, the light is reflected by the north-facing mirrors directly back into the aperture from which it comes. However, if the compass card is deflected by a change of heading of the vehicle, the beam of light strikes one or the other of the two mirrors mounted on the outside of the light housing and is reflected onto the cathode of one of the two phototubes. This fires the related thyratron, which energizes one of the electromagnetically operated clutch

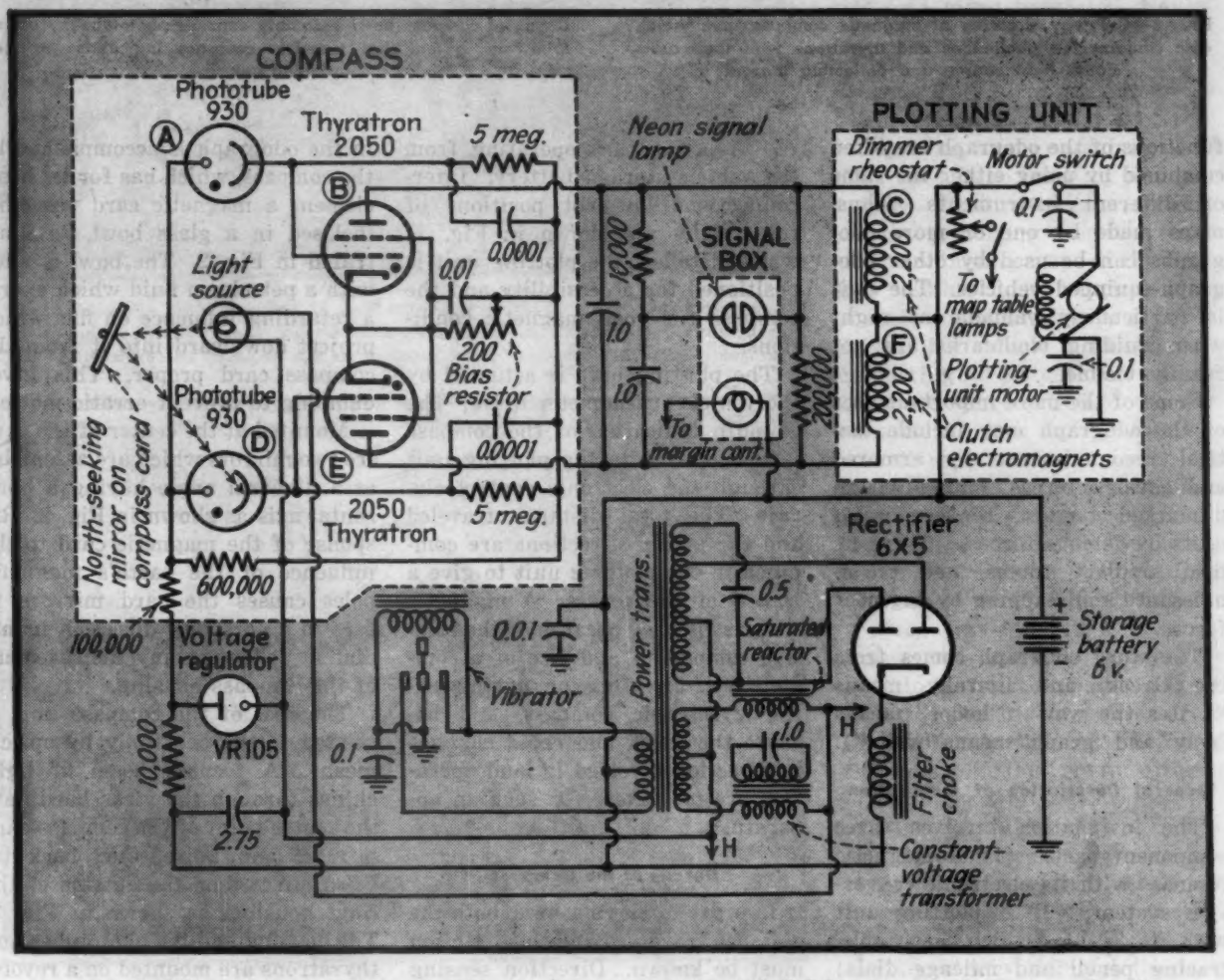


FIG. 4—Schematic circuit diagram of odograph. All parts not in the labelled boxes are in the power pack unit

speed of the system. On d-c power, only the negative element of the neon lamp glows. As shown in Fig. 4, this indicator lamp is connected so that a 1-μf capacitor discharges through it with opposite polarity as the polarities of the two thyratron plates alternate in the hunting cycle. Thus one cathode of the neon lamp represents one of the thyratrons and its electromagnet, and the other cathode represents the other combination. Any variation in hunting action can be detected by observation of this signal lamp.

The signal box also contain an incandescent lamp which comes on to signal the approach of the tracing pencil to the margin of the plotting table. Other lights are provided for illuminating the map table, and can be controlled in brilliance by a dimmer resistance to provide operation on a brightly lighted street or, at the other extreme, in complete darkness where light must not be visible from the air.

Power for the recording odograph is obtained from the storage battery of the vehicle. When the main switch is closed, the drive motor in the plotting unit is energized directly by the battery. A power pack relay is also energized, connecting the vibrator to the battery. Power supply switching circuits are omitted from Fig. 4, for simplicity.

Two voltage regulators are incorporated in the power pack. A VR105 regulator tube keeps phototube anode voltages constant at approximately 105 volts despite battery voltage variations from 6 volts up to 8 volts. A resonant-type transformer in series with a saturated reactor holds the voltage of the light source and the thyratron heaters constant at 6.3 volts.

The Plotting Unit

The plotting unit shown in Fig. 5 has four functional purposes: To draw a map showing the course taken by the vehicle in which it has been installed, to register on counters the distances traveled by the vehicle, to actuate the azimuth dial indicator to show the direction the vehicle is traveling at a given instant, and to actuate the compass drive shaft for rotation of the compass table.

To achieve these purposes, the plotting unit must combine the information given by the odometer (the speedometer drive from the vehicle transmission) and by the compass in such a way that the motion is separated into north-south and east-west components. In other words, the plotting unit must perform the mathematical operation of integrating the components of $S \sin \alpha$ and $S \cos \alpha$, where S is the distance traveled and α is the angle of azimuth or heading with respect to the reference direction—usually north—maintained by the compass. This operation is achieved by means of a sine-disk and two Scotch yokes controlling an elaborate transmission and gear train arrangement serving to couple the distance input from the speedometer drive to the two lead screws controlling the movement of the pencil on the map table.

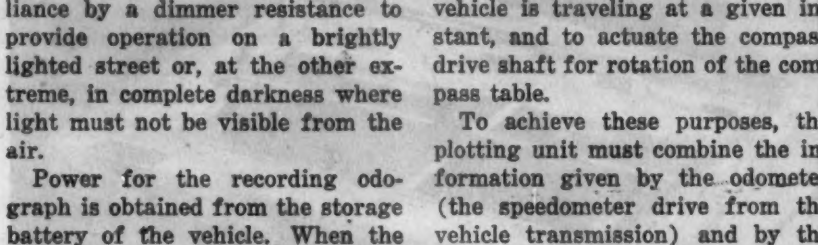
Alongside the map table on the plotting unit is a dial or azimuth indicator which repeats the reading of the completely enclosed and remotely located compass. Also on the plotting unit are counter dials that algebraically add up the two components of motion. These are calibrated in miles to give the total distance north or south and east or west of the starting point at which they were set at zero. Another set of dials is used to give the total distance travelled by the vehicle.

The scale of the map produced ranges from 1:20,000 to 1:500,000, depending on which of the available gear ratios is selected.

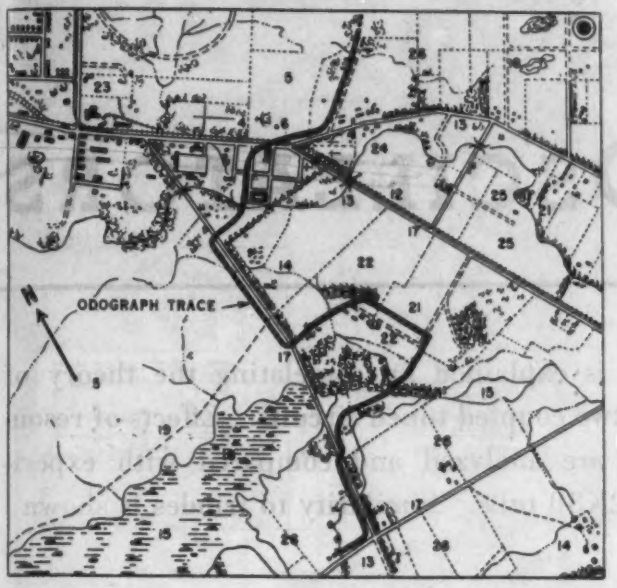
The compass is installed far enough away from the generator and other electrical equipment and wiring of the vehicle so that magnetic deviation due to these sources is eliminated. However, it is necessary that auxiliary units such as radios installed near the compass be double-wired from the battery instead of grounded to the vehicle frame, to maintain balanced magnetic fields which cancel each other.

In a vehicle containing an odograph, standard magnetic conditions are established. There are fixed positions for all tools, metal containers, and other metal objects usually carried in the vehicle and armament, and loose metal objects must be kept at least three feet away from the compass. Parking of the vehicle for a period as long as overnight requires that it be kept 15 feet away from other vehicles or else excessive changes in magnetism will result, and any changes such as removing the top or the spare tire make it necessary to recheck the compensation.

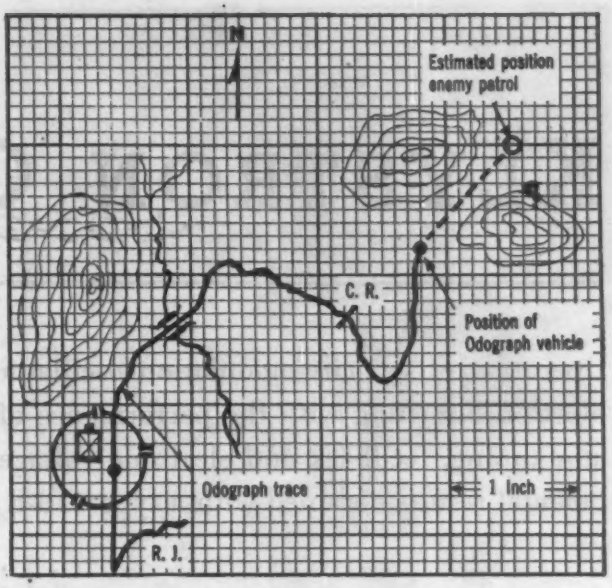
Checking of the compensation of the odograph is done by driving the



Power pack unit, containing voltage regulators, a type 6X5 rectifier, power transformer, vibrator, and reactors. Note rigid clamp for tire pump. All movable magnetic objects must be in fixed positions during operation of the odograph



Use of odograph with accurately detailed map, to reach a given objective by traveling in its general direction as necessity dictates



Use of odograph to plot on cross-section paper a rough map from which observed landmarks or enemy positions can be determined

vehicle approximately north by the azimuth dial for a distance of ¾ mile or more. The vehicle is then turned around and driven back over the exact route to the starting point. A compensator adjusting wheel is then turned to rotate the azimuth dial through half as many degrees as the angle between the north- and south-drawn traces. This procedure is then repeated on an east-west heading. When the compensation is correct, the plotting unit will exactly retrace its path on a north-south run and an east-west run.

Sources of Inaccuracy

In use, the odograph is subject to distance error, direction error, and slope distance error. The first of these, distance error, will be at a minimum when the vehicle is operated on a hard surface with standard tires at the recommended air pressure. Changes in size of tires or operations on loose or rough surfaces introduce factors which reduce the accuracy of the unit. When a vehicle becomes stuck in sand or mud, the wheels may spin considerably before the vehicle gets out. In such a case the practice is to turn off the unit until the vehicle is free. The distance input error may amount to as much as two percent under bad conditions of weather or terrain which cause an unusual amount of slippage.

Constant errors, such as those brought about by changes in tire sizes or pressures, are taken care of by a correction factor which is calculated by the average of a number of trial runs over accurately measured distances. After that, operations performed with the odograph are modified by the previously established correction factor being set in permanently as a scale change.

Direction errors are those caused by deviation from standard magnetic conditions in the vehicle, or by errors in compensation. Their correction is accomplished with appropriate compensators like those used on ship compasses. Slope-distance error is the difference between the actual distance traveled over the ground and the distance indicated by that projection on the map. In terrain with a great many hills, the odograph will show a slightly greater distance than the mileage scaled from the map. Unless an unusual series of up and down grades is involved, the error is small.

Overall accuracy on paved, unpaved, straight or crooked roads can be kept to one mile of error over 50 to 150 miles of travel. Over rough terrain, the error may be twice as great. Overall error is computed by running a closed course and observing the distance by which the trace fails to return to the starting point.

Future Uses

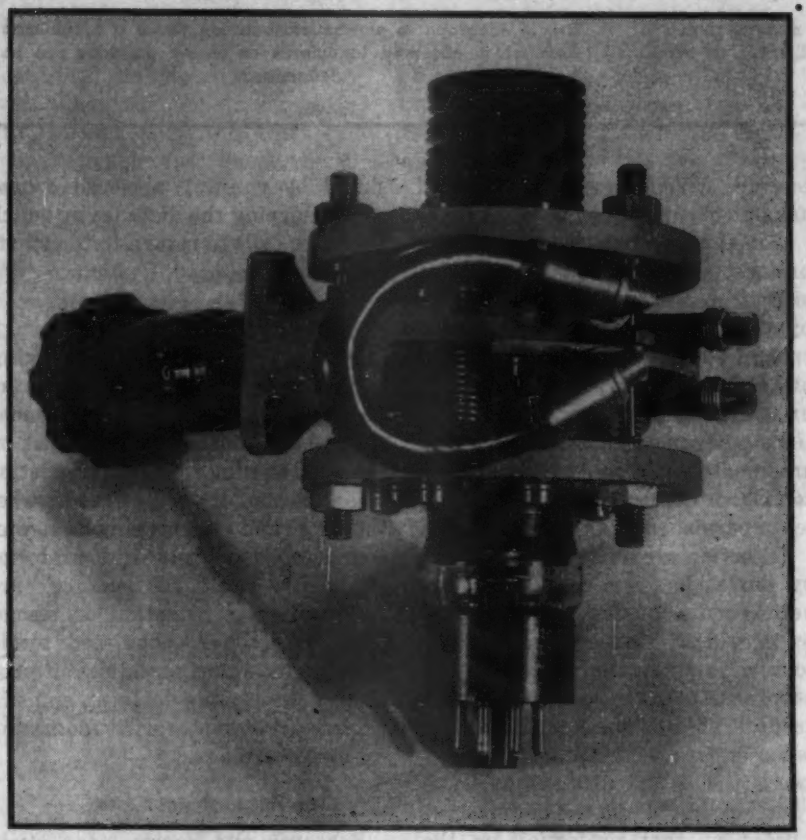
As a rapid means of surveying unfamiliar territory for the purpose of making maps, locating most favorable highway or rail routes, or simply traveling to a desired destination without the aid of landmarks, the odograph offers many post-war commercial and governmental applications. Examples are for survey, mineral exploration or rescue work in sparsely populated territory, charting of possible oil-producing sites in the desserts, and exploring polar wastes with odograph-equipped vehicles.

Acknowledgements

Research and development work on the odograph was carried out by three agencies: The Department of Terrestial Magnetism of Carnegie Institute in Washington, the Monroe Calculating Machine Co. of Orange, N. J., and the International Business Machines Corp. of Endicott, N. Y. The work was directed and coordinated by the War Department, The Office, Chief of Engineers, Engineer Board, Ft. Belvoir, Va. and the National Defense Research Committee.

KLYSTRON OSCILLATORS

Operation of velocity-modulation oscillators is explained by correlating the theory of electron bunching with the performance of two coupled tuned circuits. Effects of resonator tuning, feedback and electrode voltages are analyzed and compared with experimental results obtained with a type 410-R/2K30 tube. Similarity to triodes is shown



Type 410-R/2K30 Klystron in tuning mount, showing coaxial feedback loop, coaxial output connectors, and cooling fins

By A. E. HARRISON

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THAT Klystron* oscillators and other velocity-modulation tubes utilize electron transit-time effects to convert an electron beam into radio-frequency energy introduces certain characteristics which will undoubtedly be of interest to radio engineers. This dependence upon transit time in a Klystron oscillator causes the frequency of such tubes to be affected by the voltage applied to the tube. Another equally important characteristic which is due to the dependence upon the transit time is the occurrence of voltage modes, i.e., a Klystron oscillator will operate at certain voltages for a given adjustment of the other variables, but is inoperative in the voltage region between these modes.[1] In other respects these newer types of tubes are quite similar to the more familiar triode oscillators, and it will be convenient to use these comparisons in an explanation of the characteristics described above.

* Registered Trademark of the Sperry Gyroscope Company, Inc.

Review of Bunching Theory

A brief review of the principle of electron bunching will be made in order to compare the characteristics of velocity-modulation tubes with the plate current characteristics of more conventional vacuum tubes. The results from an analysis of coupled tuned circuits can then be combined with the tube characteristics obtained from the electron bunching theory to explain the behavior of Klystron oscillators as adjustments are made of the tuning of the resonators, or as the voltage applied to the tube is varied. The effect of the phase and the magnitude of the feedback will also be considered, and the theoretical conclusions will be compared with experimental results obtained from

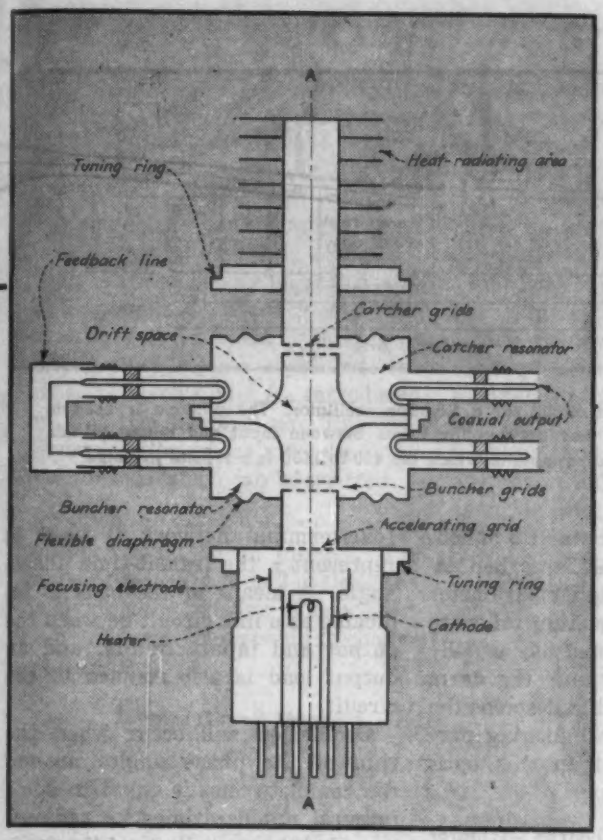
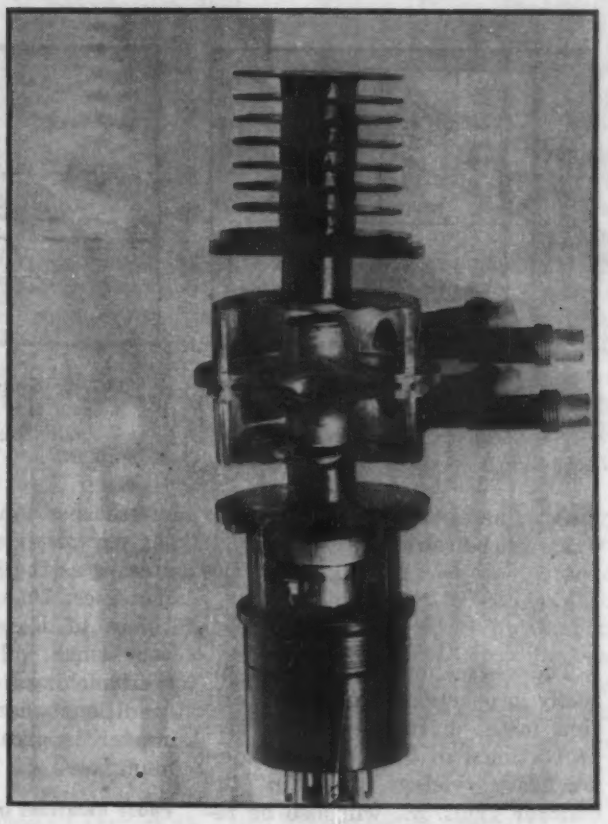


FIG. 1—Sectional view of the double-resonator Klystron of the type discussed in the text



Cutaway photograph of the interior of the 410-R/2K30 Klystron. The electron gun projects partly into the standard octal base

the operation of a type 410-R/2K30 Klystron used as an oscillator.

References to the theory of electron bunching have appeared in a number of publications[2,4]. A short review of this material will aid in the understanding of velocity-modulation tubes.

The sectional view of one type of Klystron which is shown in Fig. 1 will be used to explain the theory of electron bunching. The tube is a figure of revolution about the axis AA. An electron gun furnishes a beam of electrons which are accelerated in the space between the cathode and the accelerating grid. The beam continues to move beyond this grid with a high average velocity, and therefore the transit time of the electrons past the resonator grids corresponds to a small fraction of a cycle. The fact that the electrons are accelerated to a high velocity before being acted upon by a radio-frequency field overcomes one of the disadvantages of triodes at ultrahigh frequencies.

A radio-frequency field in the buncher resonator produces an alternating electric field between the buncher grids. This field will speed up certain electrons and slow down other electrons which pass the buncher grids during a different part of the cycle. Consider a group of electrons which pass the buncher grids at the time when the field is changing from a retarding field to an accelerating field. An electron which leaves early in the cycle will be slowed down and will continue along the drift space with less than average velocity. An electron which passes the grids when the field is zero will not be affected and will continue with average velocity. Other electrons which leave later in the cycle will be accelerated and will move along the drift space with greater-than-average velocity. The variation of velocity will be small compared to the average velocity.

As a result of this velocity modulation, electrons which leave later in the cycle travel faster and overtake the slower electrons which left earlier in the cycle. The electron beam is given an alternating component of its electron density as it travels along the drift space. This conversion process requires time; a transit time in the drift space corresponding to several cycles is typical. This transit time is quite important in the analysis of a Klystron oscillator, and the number of cycles corresponding to the transit time in the drift space will be designated by N. The electron bunches center around those electrons having average velocity, and therefore the value of N is determined by the average velocity. The following relations between the frequency f, drift distance s, transit time T, transit angle τ, average velocity v_0, and the acceleration voltage E_0 will be used frequently.

$$N = \tau/2\pi \qquad (1)$$

$$N = fT = fs/v_0 \qquad (1a)$$

The average velocity is related to the acceleration voltage by

$$v_0 = \sqrt{\frac{2e}{m}} E_0 \qquad (2)$$

where e and m are the charge and

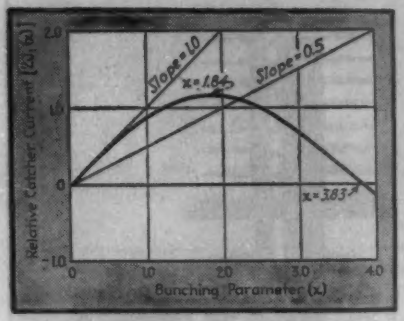


FIG. 2—Klystron bunching characteristic curve, analogous to E_g-I_p curve of ordinary tubes

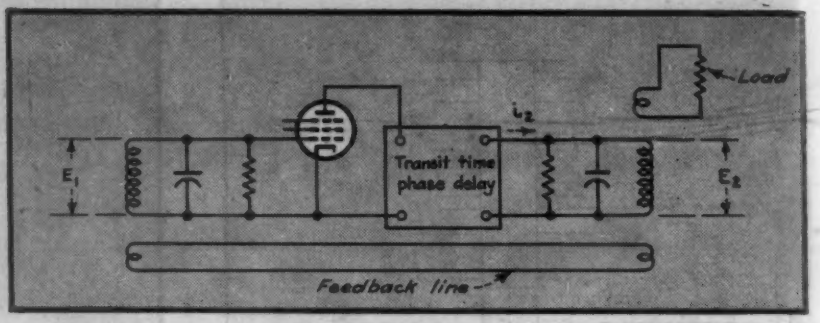


FIG. 3—Equivalent circuit for a Klystron oscillator. The pentode is used to indicate that only electron coupling exists between input and output in this velocity-modulated tube, of which the 410-R/2K30 is a typical example

mass of an electron. Therefore Eq. (1a) can be rewritten

$$N = \frac{fs}{\sqrt{\frac{2e}{m}E_0}} \qquad (1b)$$

The degree of bunching is directly proportional to the transit time in the drift space and is also proportional to E_1, the peak radio-frequency voltage between the buncher grids. E_1 will also be referred to as the buncher voltage. The degree of bunching is expressed by a bunching parameter which will be designated x, whose value is given by

$$x = \pi N \frac{E_1}{E_0} \qquad (3)$$

which with Eq. (1b) gives

$$x = \frac{\pi fs}{\sqrt{\frac{2e}{m}}} \frac{E_1}{E_0^{3/2}} = \sqrt{\frac{m}{8e}} \frac{\omega s E_1}{E_0^{3/2}} \qquad (3a)$$

The radio-frequency component of the bunched beam current, frequently called the catcher current, will be designated i_2 and is related to the bunching parameter by the expression

$$i_2 = 2I_0J_1(x), \qquad (4)$$

where I_0 is the d-c beam current and J_1 is a Bessel function of the first order and first kind. This relation is illustrated by Fig. 2. The curve will be recognized as the Klystron bunching characteristic which has been described frequently.[3, 4] This curve may be considered analogous to an I_p vs. E_g characteristic for a conventional vacuum tube where relative catcher current corresponds to I_p and the bunching parameter corresponds to E_g, although it differs in appearance because the output reaches a maximum at a bunching parameter of 1.84, and then decreases as the bunching parameter increases. Underbunching refers to values of less than 1.84, usually very small values, and the term overbunching is used to describe the conditions when the bunching parameter is greater than this optimum value.

Phase Relations in a Klystron Oscillator

These principles of electron bunching will now be applied to the analysis of a Klystron oscillator. Any amplifier will oscillate if the gain of the tube is greater than unity and sufficient energy to overcome tube losses is returned from the output to the input in the proper phase.

An equivalent circuit for a Klystron oscillator is shown in Fig. 3. A multiple-grid tube is shown to emphasize the fact that only electron coupling exists between the elements of this type of velocity-modulation tube. The input and output circuits are completely isolated unless a means of feedback is supplied. The voltage between the grids of the buncher resonator is E_1 and this voltage is also indicated as the voltage across the input circuit of the equivalent diagram. A voltage E_2 is shown across the output circuit, and represents the voltage between the grids of the catcher resonator.

A current i_2 is shown flowing into the output circuit. This current represents the radio-frequency component of the bunched beam current, and is related to the input voltage E_1 by Eq. (3) and (4). A four-terminal network is used to represent τ, the transit-time phase-angle. A means of feedback is indicated as a link circuit between the output and input circuits, and an output load is also coupled to the circuit.

Oscillation will occur when the sum of the phase angles around the complete loop is equal to some integral number times 2π radians, provided the magnitude of the feedback is sufficient to maintain oscillation. J. R. Ragazzini has suggested the diagram in Fig. 4 to illustrate these phase angles and the relations between them. The electrons which passed the buncher grids at zero phase (i.e., when E_1 was zero and changing from deceleration to acceleration) become the center of the bunch. These electrons correspond to a maximum value of the electron current and arrive at the catcher grids after a phase delay equal to τ. This phase delay corresponds to slightly less than $2\frac{1}{4}$ cycles in Fig. 4 and is indicated by an oblique line connecting the zero axes of the E_1 and i_2 curves.

In order to transfer maximum energy to the resonator field, the electrons in the bunch must pass the catcher grids when the resonator field is a maximum and in a direction which will decelerate the electrons. The current in the equivalent circuit must be in phase with the voltage if maximum power is to be transferred. This means that i_2 is a minimum when the electron current is a maximum. The transit phase angle τ corresponds to the phase between a zero value of E_1

and a negative peak of i_2 and therefore the phase angle between E_1 and i_2, introduced by the transit time and bunching considerations, is equal to $(\tau + \pi/2)$.

A phase angle ϕ_2 between i_2 and the catcher voltage E_2 is shown because E_2 need not be in phase with i_2. However, this phase angle is not used in this analysis of oscillator theory. The angle ϕ represents the phase between i_2 and E_1, introduced by the two coupled circuits. The phase relation which must be satisfied for oscillation can be written

$$\tau + \pi/2 + \phi = 2\pi n \qquad (5)$$

where n must be an integer. The value of n in Fig. 4 is 3 cycles. If τ is changed by varying the acceleration voltage, a corresponding change in ϕ must occur.

Coupled Circuit Theory

An analysis[5] of the phase relations in two tuned coupled circuits shows that ϕ will change if the frequency of oscillation is varied. These conditions explain the fact that the frequency of a velocity-modulation oscillator varies when the acceleration voltage is changed, in order to maintain the necessary phase relations.

The equivalent circuit in Fig. 3 shows that a Klystron oscillator may be considered as two parallel resonant coupled circuits, fed by a constant-current source i_2. The analysis of such a circuit to obtain the phase and magnitude of the voltage across the primary and secondary can be obtained, with some slight modifications, from radio engineering handbooks and other sources.[5,6,7] This information about the phase and magnitude of the feedback can then be combined with the bunching characteristic of a Klystron tube, as illustrated by Fig. 2 and Eq. (4), to obtain a prediction of the output characteristics of a Klystron oscillator as the acceleration voltage is varied.

Certain assumptions will be made to simplify the analysis. The resonant frequencies of both circuits will be considered identical; this assumption will make the characteristics symmetrical with respect to frequency. A feedback line of zero length will be assumed so that the analysis for lumped constant circuits at low frequencies can be used. The Q of the two circuits will not be equal because one circuit has been loaded. The Q of the output circuit in Fig. 3, which corresponds to the primary of the two coupled circuits, will be considered half as great as the Q of the input circuit, which corresponds to the secondary. Calculations will be carried out for two degrees of coupling between the two circuits. In one case the coupling will be assumed five times greater than the value for critical coupling, and critical coupling will be assumed for the second case.

Curves of primary and secondary voltage as a function of frequency are usually given in the reference texts[5]. The curves in Fig. 5 will be recognized as typical illustrations of these characteristics for two coupled tuned circuits. Ratios of E_1/i_2 and E_2/i_2 are plotted so that unit coordinates may be used, and the maximum ratio of E_1/i_2 is indicated by a value of unity. Increasing the value of i_2 will increase the value of voltage across the circuit but will not affect the ratio. The phase relation between i_2, the constant-current source in

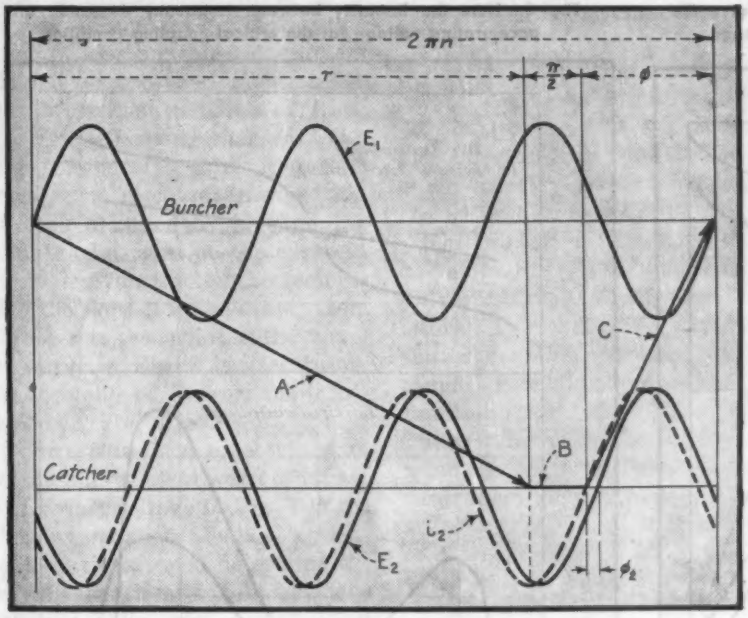


FIG. 4—Phase relations in a Klystron oscillator. The phase change from buncher to catcher along the electron beam drift is represented by vector *A*. The phase shift between the bunched electron stream and the catcher resonator-field current component is represented by vector *B*. The phase shift due to the coupling from the catcher to the buncher is represented by vector *C*. The transit-time phase-angle is represented by the angle τ

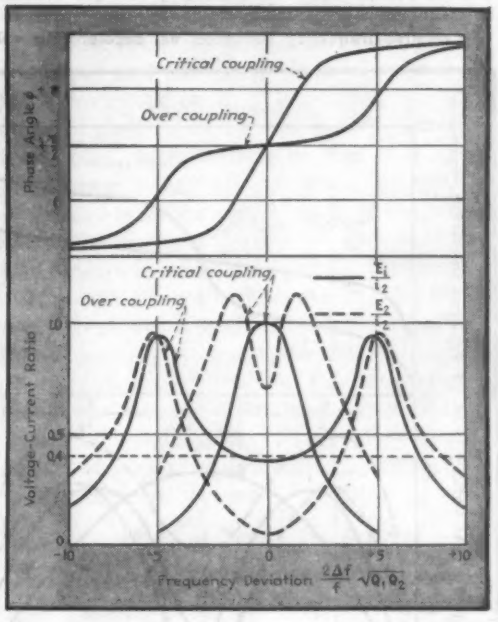


FIG. 5—Phase and voltage relations in coupled circuits where the primary Q is half the secondary Q. The over-coupling condition is for five times critical coupling. The phase angle at the top of the graph is that between primary (catcher) current and secondary (buncher) voltage

the analysis, and secondary voltage E_1 is also shown as a function of frequency.

The form of the curves in Fig. 5 is not ideally suited to the analysis of a Klystron oscillator where the frequency is dependent upon the beam voltage as well as upon the tuning. To examine the behavior of such an oscillator as the acceleration voltage is changed, it will be convenient to replot the frequency as a function of voltage. This step is illustrated by the frequency vs. voltage curves in Fig. 6, which correspond to Fig. 5.

The previous discussion has concerned only the coupled circuit theory. It is necessary to relate these results to the bunching characteristic of a Klystron tube, shown in Fig. 2, in order to complete the analysis and obtain the power output curves shown in Fig. 7.

The Klystron oscillator characteristic illustrated by Fig. 8, which has been obtained by modifying the presentation of the information in Fig. 2, has been used to convert the data in Fig. 6 into the Klystron output characteristics in Fig. 7. Frequency curves have been transferred directly to the corresponding figures, for the values of acceleration voltage which permit oscillation.

Oscillator Characteristics

Calculations for the procedure described briefly in the preceding paragraph are quite simple, and the steps will be outlined in detail. The relation between voltage and frequency is obtained by evaluating τ in terms of E_0, the acceleration voltage, and correlating the values of τ with values of ϕ in Fig. 5. Separate calculations must be made for each value of coupling. Values of τ for chosen values of E_0 are tabulated from

$$\tau = \frac{2\pi f s}{\sqrt{\frac{2e}{m} E_0}} \qquad (6)$$

which is obtained by equating Eq. (1) and (1b). The percent change in frequency is small, and therefore all factors except E_0 may be lumped into a single constant. Corresponding values of ϕ are obtained by substituting the values of τ into Eq. (5). These values of ϕ are used to determine the frequency which corresponds to the acceleration voltage chosen for the tabulation. Then these data are replotted to give the frequency curves in Fig. 6, and the values of E_1/i_2 and E_2/i_2 are transferred from Fig. 5 to Fig. 6, using this f-vs.-E characteristic.

The necessary correlation between the feedback circuit and the bunching characteristic of a Klystron tube (see Fig. 2), can be obtained by evaluating E_1/i_2 in terms of the bunching parameter defined by Eq. (3) and (4). Equation (3), which relates E_1 and the bunching parameter x, can be rewritten

$$E_1 = E_0 x / \pi N \qquad (7)$$

Substitution of Eq. (7) and (4) in the ratio E_1/i_2 gives

$$\frac{E_1}{i_2} = \frac{E_0}{\pi N I_0} \frac{x}{2J_1(x)} \qquad (8)$$

The ratio E_0/I_0 may be replaced by R_0, which is known as the beam resistance of the tube. Equation (8) can be rewritten

$$\frac{x}{2J_1(x)} = \frac{\pi N I_0}{E_0} \frac{E_1}{i_2} = \frac{\pi N E_1}{R_0 i_2} \qquad (9)$$

FIG. 6—These curves are for the same conditions as in Fig. 5 but are plotted against accelerating voltage, which is related to frequency by Eq. (5) and (6). The upper curves give the relative frequency deviation vs. accelerating voltage

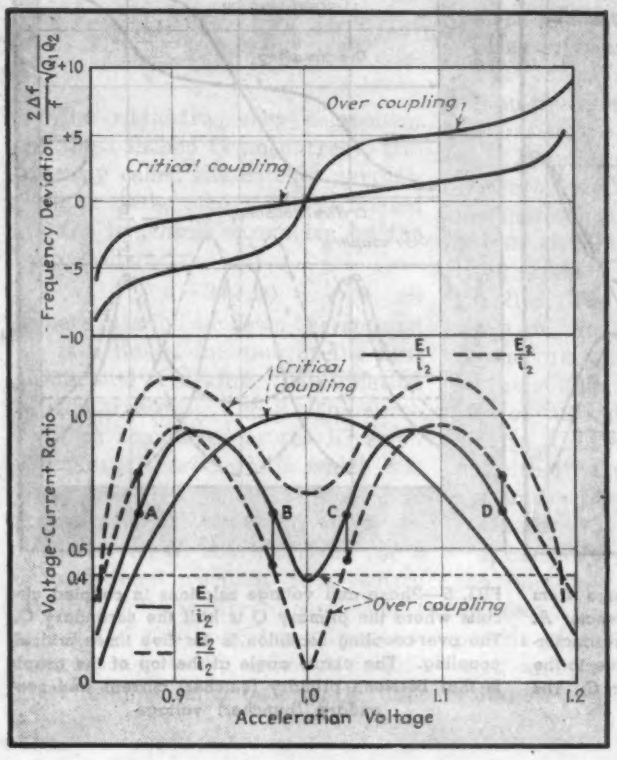
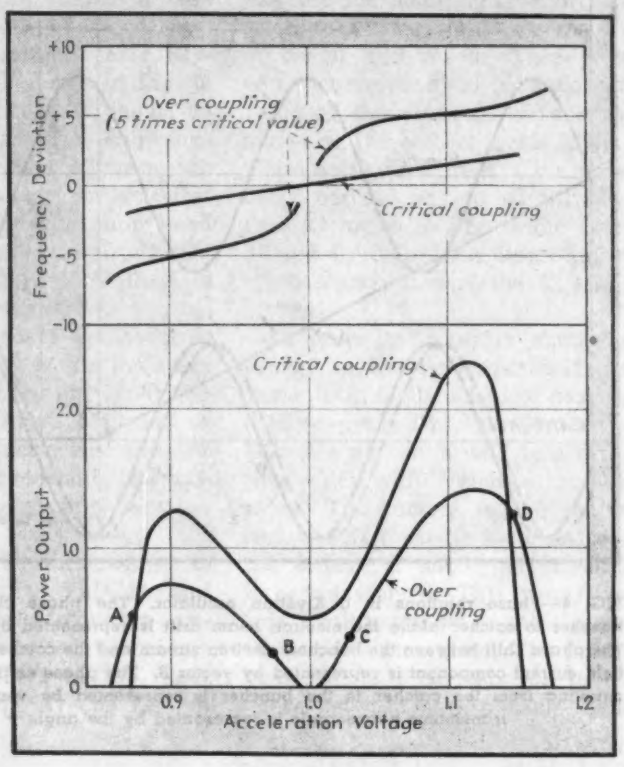


FIG. 7—Taking the power output as proportional to the catcher voltage squared, these curves are obtained from the curves of Fig. 6. Note the linearity between frequency deviation and accelerating voltage for the critical coupling condition



These equations furnish the correlation between the feedback circuit characteristic which determines E_1/i_1, and a modification of the bunching parameter.

The significance of the factor $x/2J_1(x)$ can be illustrated by reference to Fig. 2. This factor is merely another form of bunching parameter. Any line from the origin with a slope less than unity will intersect the curve at some point other than zero and less than $x = 3.83$, where the Klystron output again becomes zero. A line with a slope of 0.5 is shown, and this line intersects the curve at a point somewhat beyond the maximum. Another line with a slope of unity is tangent to the curve at the origin. This line does not intersect the curve, and represents the conditions when oscillations start. This starting-characteristic line with a slope of unity corresponds to a unity value $x/2J_1(x)$. Lines with slopes less than unity correspond to values of $x/2J_1(x)$ greater than unity, since the slope of a line is equal to the reciprocal of $x/2J_1(x)$.

Each point on the curve in Fig. 2 corresponds to some operating condition for a Klystron oscillator. It will be convenient to replot $2J_1(x)$, which is proportional to i_2, as a function of $x/2J_1(x)$. This modification of the bunching characteristic makes it possible to obtain the value of i_2 from a value of E_1/i_1, since Eq. (9) shows that $x/2J_1(x)$ is proportional to E_1/i_2. Figure 8 shows such a characteristic, and has been obtained by plotting the ordinate of a point on the curve in Fig. 2 as a function of the reciprocal of the slope of a line drawn from the origin to that point on the curve. The curve in Fig. 8 is used to obtain the value of E_2 from the information in Fig. 6.

Figure 8 is used to obtain data for the curves of power output vs. acceleration voltage in Fig. 7 in the following manner. Typical operating conditions would determine the starting conditions for the Klystron oscillator. We will assume that E_1/i_2 equal to 0.4 corresponds to these starting conditions. For this assumption, Eq. (9) can be rewritten

$$x/2J_1(x) = 2.5\,E_1/i_2 \qquad (10)$$

The dash lines in Fig. 6 represent the starting conditions for the Klystron oscillator. The acceleration voltage corresponding to the intersection of the dash line and the E_1/i_1 curve in Fig. 6 is noted. The output for this value of acceleration voltage is zero. A higher value of E_1/i_1 for a different acceleration voltage is substituted in Eq. (10) to obtain the value of $x/2J_1(x)$, and a corresponding value of $2J_1(x)$ is determined from Fig. 8.

The beam current I_0 is computed from the 3/2 power law and the acceleration voltage. The value of i_2 is then obtained by substitution of I_0 and $2J_1(x)$ in Eq. (4). E_2 is calculated from i_2 and the value of E_2/i_2 from Fig. 6 corresponding to

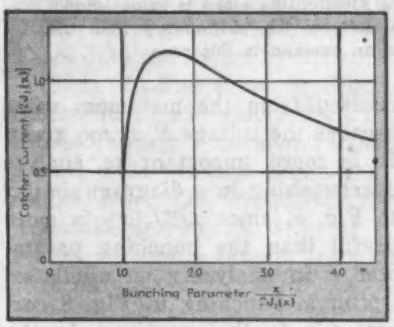


FIG. 8—A change of abscissa converts the bunching characteristic of Fig. 2 to this more convenient form

the acceleration voltage which was chosen. The power output is proportional to the square of E_2 and is plotted as such in Fig. 7. The frequency curve is transferred directly from Fig. 6 to Fig. 7.

The two sets of theoretical output curves in Fig. 7 are typical of two different types of Klystron oscillators. The curves for five times critical coupling represent a tightly coupled oscillator and exhibit the familiar pair of voltage modes. The maxima of the two modes occur when the frequency has values corresponding approximately to $\phi = 0$ and $\phi = \pi$ in Fig. 5. If these values of ϕ are substituted in Eq. (5), the value of τ is given by

$$\tau \cong 2\pi\,(n \pm 1/4) \qquad (11)$$

Equation (11) is often stated in the form, "The number of cycles of oscillation during the transit of an electron from the buncher to the catcher is an integer plus or minus one quarter." It should be noted that this statement is a special case which does not apply to all Klystron designs.

The more loosely coupled oscillator illustrated by the critical coupling curves of Fig. 7 has the two modes merged into continuous output. The latter characteristic is typical of the type 410-R/2K30 Klystron oscillator, and differs from overcoupled types which exhibit two separate families of voltage modes.

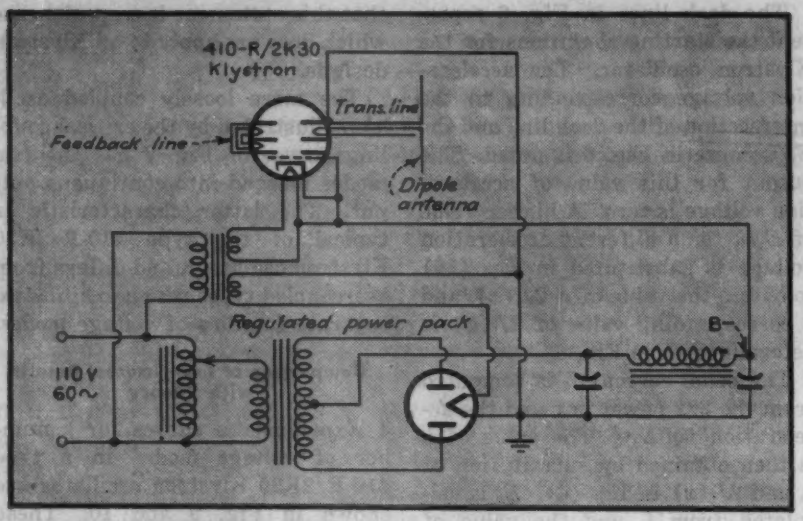
Comparison of Experimental Results with Theory

Experimental curves for a number of voltage modes in a type 410-R/2K30 Klystron oscillator are shown in Fig. 9 and 10. These curves were obtained by a dynamic method which eliminated tuning changes due to thermal variations caused by changing the power input to the tube. The similarity of Fig. 9 to the theoretical curve in Fig. 7 for critical coupling indicates that the assumptions used in obtaining the theoretical curve are reasonably good. The equal height of the two peaks of each mode in Fig. 9 was obtained by purposely detuning the tube to produce the flattest characteristic, and does not represent a deviation from theory. Detuning the tube in the opposite direction emphasizes the higher voltage peak and produces maximum power output and efficiency. This effect is illustrated by Fig. 10.

Note that the frequency deviation characteristic in Fig. 9 is almost linear with accelerating voltage over the useful range of output. This characteristic is gained by some sacrifice in power. (Compare with Fig. 10). Because of this, the type 410-R/2K30 Klystron is quite useful as an oscillator in frequency-modulation circuits. The frequency modulation is obtained by varying the acceleration voltage. However, considerable modulation power is required.

Effect of Tuning the Klystron

The effect of tuning the Klystron oscillator, as described in the discussion of the output characteristics in Fig. 9 and 10, can be derived from circuit theory but the details will be omitted. Certain important conclusions can be obtained from a qualitative analysis of the over-



Basic Klystron oscillator circuit, showing the extreme simplicity of the voltage requirements. Like all electron oscillators the frequency is affected by the power pack voltage, but in the case of the Klystron the effect is large (shown in Fig. 9). A coaxial transmission line delivers the uhf energy from the oscillator to the load, which is an antenna in this case

coupled case, and the general nature of these results applies equally well to the behavior of the type 410-R/2K30 Klystron. However, electron bunching theory must be considered in some detail before returning to a discussion of the effect of tuning.

One of the principal factors in the explanation of Klystron oscillator power output characteristics is introduced by the variation of i_2, the radio-frequency component of the bunched beam current, as the value of E_1 is increased. Figure 2 and Eq. (3a) and (4) illustrate this variation of the radio-frequency current. The term overbunching is applied when the current is decreased from the maximum value because the voltage E_1 is too great. It is more important to analyze overbunching in a diagram similar to Fig. 8, since $x/2J_1(x)$ is more useful than the bunching parameter x in analyzing an oscillator. Optimum bunching in Fig. 8 corresponds to the maximum in the curve when $x/2J_1(x)$ is equal to 1.59, which corresponds to a value of 0.635 for E_1/i_2. Larger values of E_1/i_2 cause overbunching.

Overbunching does not necessarily reduce the output. Note in Fig. 6 that the ratio E_2/i_2 is increasing rapidly at the acceleration voltages corresponding to points A, B, C, and D, which represent the ratio of E_1/i_2 required for optimum bunching. Increasing the ratio of E_1/i_2 above the optimum value does not reduce i_2 very rapidly, since i_2 is proportional to $2J_1(x)$, and Fig. 8 shows that this factor decreases slowly beyond the point of optimum bunching. The increased E_1/i_2 ratio allows the output to increase in the region between A and B, also in the region between C and D. Corresponding points have been marked on Fig. 7 to illustrate this effect.

Any deviation from identical tuning will decrease one peak in the E_1/i_2 curve when the losses in the two resonators are unequal. The other peak may remain approximately the same, or it may increase slightly, depending upon the ratio of the losses in the two resonators. The effect of detuning the buncher resonator to a lower frequency, leaving the catcher resonator tuned to the frequency corresponding to the identical tuning represented in Fig. 5, is illustrated in Fig. 11 for the case when the losses in the catcher resonator are twice as great as the losses in the buncher resonator. Both patterns are moved in the direction of lower frequency and the patterns are no longer symmetrical. The higher-frequency peak in E_1/i_2 is reduced and the corresponding peak in E_2/i_2 is increased.

As a result of the detuning, the degree of overbunching in the high-frequency mode will be less and i_2 will increase. Since E_2/i_2 has also

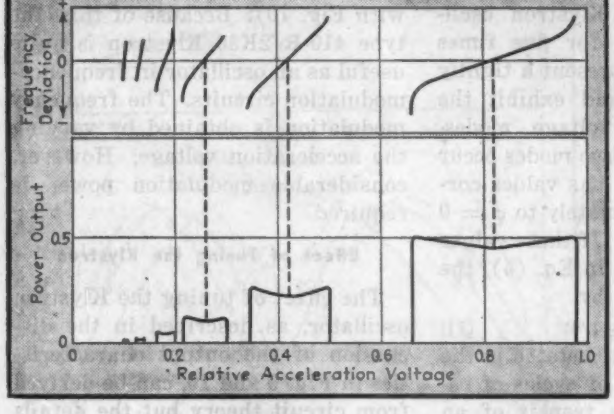


FIG. 9—Experimental characteristics for 410-R/2K30 Klystron oscillator with critical coupling. The tuning was adjusted to give flat output. Compare these curves with the critical coupling curves of Fig. 7

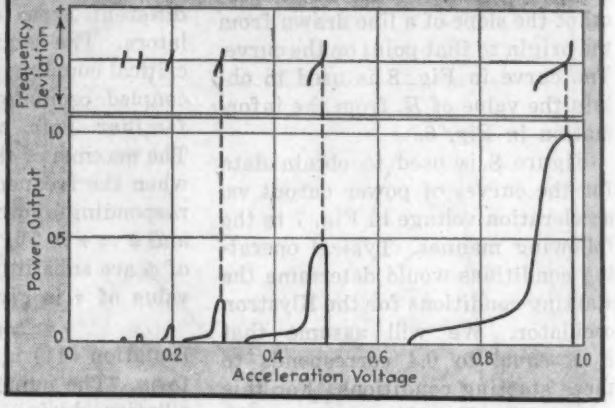


FIG. 10—By adjusting the tuning, the output can be made a maximum. This has been done to obtain these experimental curves. One peak is accentuated at the sacrifice of the other. Operation is more critical of accelerating voltage

been increased by the detuning, the output of this mode will increase considerably. In contrast, the over-bunching remains about the same in the lower-frequency mode but the ratio of E_2/i_2 is decreased, and therefore the output of this mode decreases slowly. However, the ratio of E_1/i_2 for the higher-frequency mode can be reduced to the value corresponding to the starting conditions while the lower-frequency peak in E_1/i_2 remains greater than this value. This relation means that continued detuning of the buncher resonator to a lower frequency causes the higher-frequency mode to increase at first, then disappear before the lower-frequency mode is eliminated. The frequency of the higher-frequency mode approaches the frequency of the tuning of the catcher resonator. The lower-frequency mode can be accentuated by detuning the buncher resonator to a higher frequency than the tuning of the catcher resonator.

Effect of Length of Feedback Line

The previous discussion has been based upon a zero length of feedback line. This assumption obviously does not apply to a type 410-R/2K30 Klystron, since an external feedback line of considerable electrical length must be used. The problem is complicated when the line is not terminated with its characteristic impedance. However, it is fairly satisfactory to assume that the phase shift in the line can be represented by an angle ϕ_L, and rewrite Eq. 5 in the form

$$\tau + \frac{\pi}{2} + \phi + \phi_L = 2\pi n. \qquad (12)$$

The logical conclusion from Eq. (12) would be that the acceleration voltage, which determines τ, could be arbitrarily chosen by adjusting the length of the feedback line. Some choice of the operating voltage is permitted by such an adjustment. However, the feedback line is not usually matched, and certain line lengths prevent operation at the frequency which may be required. Therefore, it is not always possible to correct for changes in the transit time by changes in the length of the feedback line. As a result, there are some regions of acceleration voltage where oscillation can not be obtained by any simple adjustment of the tube or feedback line.

All of the previous discussion is influenced by the output load which is connected to the tube, but this effect has been included implicitly in the assumption that the losses in the output resonator were twice as great as the losses in the buncher resonator. This assumption is equivalent to the statement that the resonators are identical and that the power transferred to the load is equal to the power losses in the output resonator itself.

Power Output

Data have been obtained which relate the output power which can be transferred from a Klystron oscillator to a given load resistance. These data are shown by the points in Fig. 12. The curve in Fig. 12 represents a constant-current source feeding a parallel resonant circuit with internal losses and a coupled load. The theoretical curve was made to coincide with the observed maximum output from the Klystron oscillator. Zero load resistance in this illustration corresponds to a light load, i.e., the load resistance is an equivalent series resistance. The agreement between the experimental points and the theoretical curve in the region beyond the maximum output fails because the Klystron does not oscillate when the load becomes too great.

Conclusions

It is apparent that the characteristics of velocity-modulation tubes must be considered carefully when equipment is designed to use these tubes. In some respects these tubes are similar to the more familiar types of vacuum tubes. They can be used as oscillators or amplifiers, and when equipped with the proper resonators, they can also be used as frequency multipliers. Klystron oscillators are more dependent upon the voltage applied to them than triode vacuum tubes, and both frequency and output will vary if the voltage is changed. Operation is possible at a number of different voltage modes, but oscillation does not occur in the region between these modes. When these characteristics are either used or circumvented in the design of the equipment, these factors do not limit the application of the tubes and actually make it possible to accomplish results which are difficult to achieve in any other way.

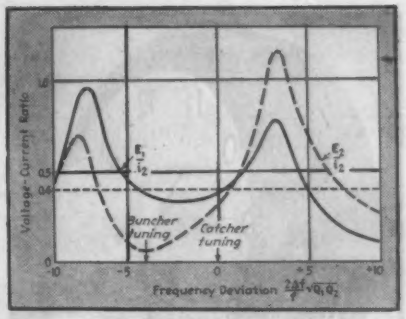


FIG. 11—Detuning the buncher to a lower frequency shifts the peaks to lower frequencies. Except for this detuning of the buncher, these curves represent the same conditions as those illustrated by the over-coupling curves of Fig. 5

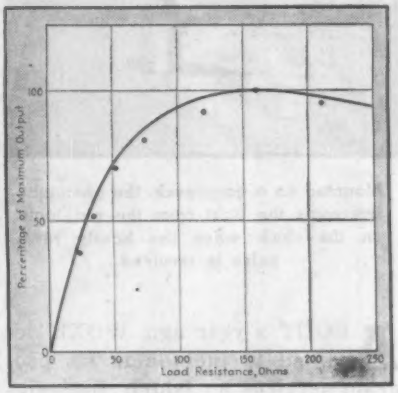


FIG. 12—Theoretical output curve and experimental output points measured for the 410-R/2K30 Klystron oscillator

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Dual Time

Ingenious method of automatically broadcasting an hourly chime signal and synchronizing a remote transmitter clock with the studio clock. Both operations are initiated by a pulse from a Western Union master clock line without making any direct connections to the circuit

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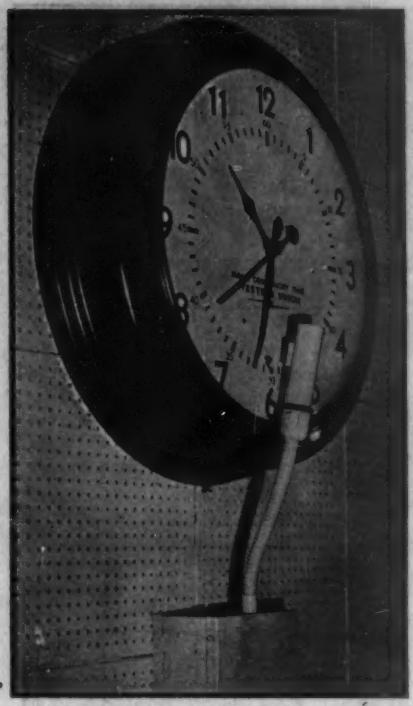


Mounted on a gooseneck, the phototube intercepts the light from the red lamp on the clock when the hourly reset pulse is received

ABOUT a year ago, WQXR decided to include in its program services an hourly time signal. It was felt that this time signal should not be the customary harsh "beep," but rather a musical chime consistent with the station's classical programs.

Finding a suitable tone at first posed a problem. Numerous schemes were tried and discarded for one reason or another. Finally a single-plate electromagnetic door chime provided the answer.

As shown in Fig. 1, a hole was cut in the top of the chime case to accomodate a 2000-ohm headphone. With the cap and diaphragm removed, the headphone functions as an inductive microphone, with the chime plate serving as a diaphragm. The headphone should be mounted fairly close to the chime plate, the distance between them in a large measure determining the output.

The degree of damping or hangover of tone is controlled by means of a set screw and lock nut which is threaded through the top of the chime case to one end of the chime plate. The surface of the plate at the point of contact is covered with a thin layer of felt.

A variable resistance, placed in series with the chime solenoid, is adjusted to give positive operation and reduce the thump which occurs if too high a voltage is applied. Proper spacing between the chime plate and phone, the correct amount of damping, as well as application of the required solenoid voltage, will result in a rather pleasing tone. Construction of this signal source is simple and inexpensive.

Hourly Pulse Problem

To operate the chime, Western Union was asked to supply a line similar to the one used to pulse-reset WQXR's master control room clock. Western Union was prepared to do this but pointed out that WQXR is on a "master clock circuit" which includes an additional pulse fifteen minutes after the hour. The clock reset mechanism is so designed that the fifteen-minute pulse does not operate the reset relay. They said that in most stations using the service for time signals the engineer manually opens the circuit after the hourly pulse and closes it again some time after the fifteen-minute pulse.

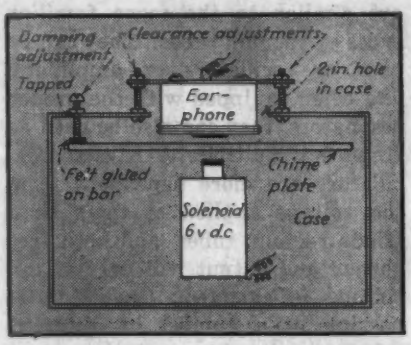


FIG. 1—Method of mounting the headphone on the case of the door chime

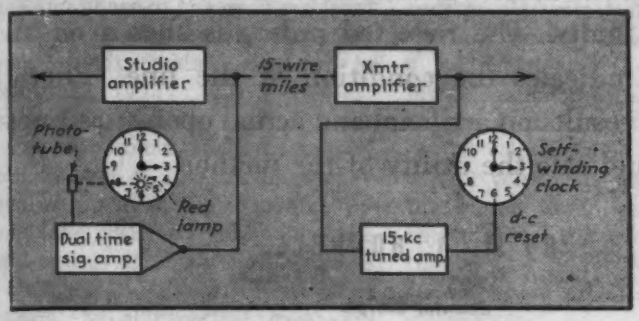
Since it was desired to make our time signal completely automatic as well as distinctive, this method was deemed unsatisfactory.

The control room clock contains a red lamp that lights only on the hourly reset pulse. If the chime could be connected to the lamp circuit, a ready answer to the pulse problem would be provided. For some reason, however, Western Union was unable to supply, or grant permission to connect a pair of wires from the lamp circuit to operate the chime.

Speculating on the matter further, we thought, "Well, there's nothing wrong with looking at the red light!" This we did, and with a phototube.

As can be seen from the diagram of Fig. 2, the time signal picked up by the phototube is amplified and energizes a sensitive relay; this in turn operates the chime. The tone is picked up in the headphone and then fed to the WQXR

Signal at WQXR



Block diagram of complete system for transmitting an hourly chime signal and pulsing the transmitter clock at the same time

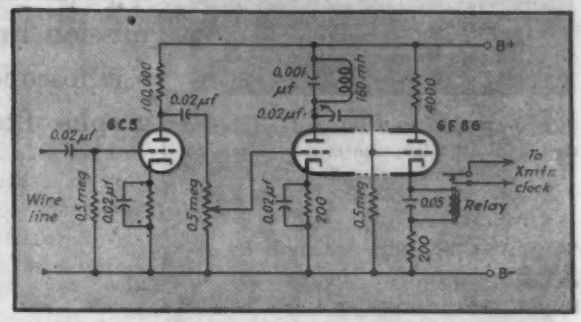


FIG. 3—This bridging amplifier closes the transmitter clock reset circuit when the 15-kc signal comes over the studio line

transmitter over the wire line.

For years we had wanted a Western Union clock at the transmitter for time synchronization with the studio. The idea had to be abandoned, however, as no reset pulse circuits were available at our transmitter location.

Synchronizing Studio and Transmitter Clocks

After the Western Union red-light phototube-controlled time signal was put into operation, the thought occurred that the phototube might simultaneously be put to work to reset a clock at the transmitter.

Using the phototube as the motivating force to bring a pulse from the studio in New York to the transmitter in Long Island was a relatively simple matter. This was accomplished by installing at the studio a 15-kc RC oscillator combined with a dual amplifier so that both the time tone and the transmitter clock-reset tone (15-kc) are sent simultaneously over the speech line to the transmitter. The circuit of both of these units is shown in Fig. 2.

The time tone is thus fed directly to the transmitter through the transmitter speech equipment. The 15-kc clock-reset tone is picked up at the output of the transmitter line speech amplifier through a 15-kc tuned bridging amplifier.

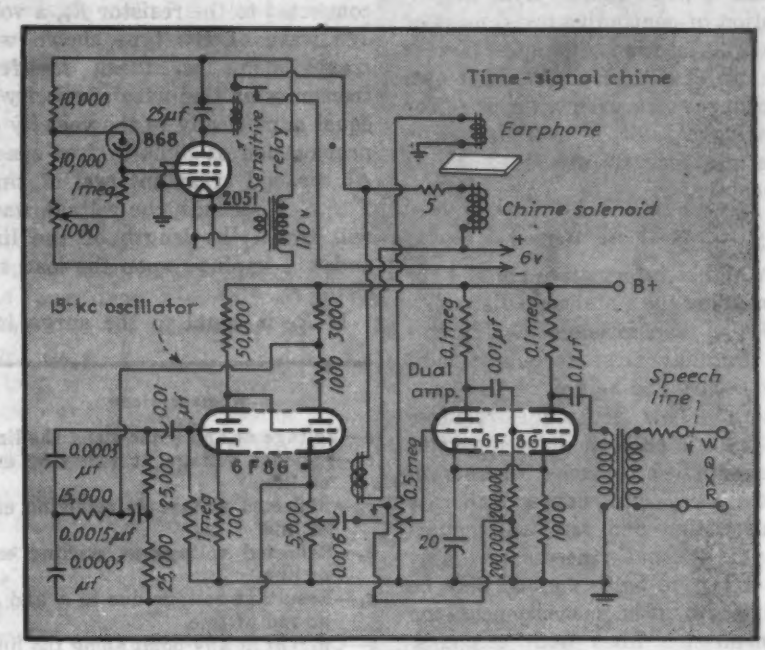


FIG. 2—Complete circuit of equipment installed at the studio. When the red lamp flashes on the clock, the phototube amplifier operates the chime and permits the 15-kc oscillator to feed a signal to the transmitter

This unit is shown schematically in Fig. 3. A plate-circuit relay in the bridging amplifier serves to close the transmitter clock reset circuit.

Independent volume controls are used on the time-tone and the 15-kc signals, with both set to leave the studio at −10 vu. This level for the time tone is not too loud, yet permits the signal to be heard through voice. At this line input level, the 15-kc signal arrives at the tuned bridging amplifier with sufficient amplitude for positive relay operation. Power for the amplifiers is obtained from the regular speech-amplifier power supplies.

Those stations not using a high-quality line could still reset a transmitter clock from the studio by use of an 8 to 10-kc pulse and possibly a slightly higher level. The 15-kc tone can be heard over WQXR if a good receiver and loudspeaker are used. The system has given fool-proof and maintenance-free service since its installation a year ago.

LOCATION of

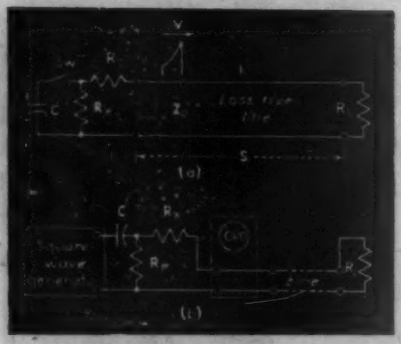


FIG. 1—Basic circuit (a) and measuring circuit (b) used in pulse measurements on transmission lines

A pulse technique determines location and nature of transmission line faults. The reflected pulse, as shown on an oscilloscope, indicates the condition of the line. Photographs of test results on artificial and actual open-wire lines indicate the utility of the method

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MANY techniques have been developed for the location of faults on transmission lines. Each specific method presents certain advantages for the location of a particular type of fault.[1] With the exception of continuity tests, most of the fault location techniques involve the use of a bridge. A well-known impedance measurement method for locating a fault on a transmission line was recently described in the literature.[2]

The Pulse Method

A highly informative method for measuring the distance to discontinuities on transmission lines utilizes the familiar pulse technique used to measure the height of the ionosphere.[3] This technique requires the use of a pulse-modulated carrier when applied to measurements in free space, and hence elaborate transmitting and receiving apparatus are usually necessary. Fortunately, the pulse method may be utilized to make measurements on transmission lines with comparatively simple apparatus.

This paper describes an experiment originally developed to give students a background of visual experience with travelling waves and reflection phenomena. Tests on a 146-mile open-wire line from Atlanta to Birmingham indicate that the pulse technique will accurately measure the distance to several discontinuities simultaneously present on a line.

Travelling Waves on an Ideal Line

A lucid treatment of the subject of travelling waves on transmission lines is presented in standard texts.[4]

Referring to Fig. 1(a), if a charged capacitor is momentarily connected to the resistor R_p, a voltage wave of the type shown will travel along an ideal, loss-free transmission line with a velocity V equal numerically to the velocity of propagation of light in free space. At the end of an interval of time $T = S/V$ seconds, the voltage wave will travel the length of the line and will impinge upon the load resistor R_L.

If R_L is equal to the surge impedance $Z_0 = \sqrt{L/C}$ of the loss-free line, the energy of the wave is completely absorbed by R_L, and no reflection takes place. On the other hand, if R_L is not equal to Z_0, there will be a partial reflection of the incident wave by R_L. The magnitude and phase of the reflected wave depends upon the magnitude of the departure of R_L from the value of Z_0 according to the equation

$$e_R = e_I (R_L - Z_0)/(R_L + Z_0) \quad (1)$$

It is apparent that if R_L is greater than Z_0, the reflected voltage wave is not reversed in sign; but if R_L is smaller than Z_0, the reflected voltage wave is reversed in sign. In the limiting cases, when the line is open-circuited, R_L is infinite in magnitude, and $e_R = e_I$; when the line is short-circuited, R_L is zero, and $e_R = -e_I$.

The voltage wave is necessarily accompanied by a current wave directly related to the voltage wave by the equation

$$e/i = \sqrt{L/C} = Z_0 \quad (2)$$

The magnitude and the phase of the reflected current wave is obtained from the relation

$$i_R = -i_I (R_L - Z_0)/(R_L + Z_0) \quad (3)$$

Continuing with the observation of the voltage wave, if reflection takes place at the load, the reflected voltage wave e_R travels to the sending end of the line in the time $T = S/V$. Here again there will be either complete absorption or partial reflection of this returning voltage wave, depending upon the magnitude and nature of the sending-end impedance encountered by the re-

Nomenclature

- e—Voltage at any point along the line.
- e_I—Incident voltage at receiving end of line.
- e_R—Reflected voltage at receiving end of line.
- e_S—Reflected voltage at sending end of line.
- e_L—Resultant voltage due to e_I and e_R at end of line.
- i—Current at any point along the line.
- i_I—Incident current at receiving end of line.
- i_R—Reflected current at receiving end of line.
- C—Line capacitance per mile.
- G—Line-to-line conductance per mile.
- R—Line resistance per mile.
- L—Line inductance per mile.
- R_0—Sending-end impedance.
- R_L—Load resistance.
- R_p—Pulse generator impedance.
- R_s—Calibrated variable resistance.
- S—Length of transmission line in miles.
- T—Time in seconds required for wave to travel S miles.
- T_1—Period of a half cycle of pulse signal.
- T_s—Period of pulse signal in seconds.
- V—Velocity of propagation of pulse in miles per second.
- Z_0—Line surge impedance.

# of Line Faults

turning voltage wave. The magnitude and phase of the wave reflected from the sending end are obtained from an expression identical in form to Eq. (1):

$$e_s = e_r\,(R_G - Z_0)/(R_G + Z_0) \quad (4)$$

It now becomes apparent that if both R_G and R_L are not identically equal to Z_0, many successive reflections take place on the line until the total energy in the travelling wave is dissipated in the terminating resistors. In a practical case, the wave is also attenuated by the line losses as it travels back and forth.

Wave Velocity

The velocity of propagation of the travelling wave depends upon the characteristics of the transmission line. The velocity of propagation of the wave front is given by the expression[4]

$$V = 1/\sqrt{LC} \quad (5)$$

where L is the inductance per unit length and C is the capacitance per unit length. On the usual open-wire line with a conductor spacing which is much greater than the conductor diameter, the velocity of propagation of travelling waves approaches the free-space velocity of propagation of light. The velocity of propagation of travelling waves on cable circuits is, however, much lower than that on open wire lines. In the discussion to follow, it will be seen that the apparent velocity of propagation of a particular pulse wave on a line can be determined by placing a discontinuity at a known distance from the sending-end of the line.

Examples of Reflection

The reader is now in a position to predict the type of picture to expect on the screen of a cathode-ray oscilloscope connected to any point along an ideal transmission line. As an example, assume that $R_G = Z_0$ and that $R_L = Z_0/2$. Upon substituting these values in Eq. (4) and (1) respectively, it is seen that $e_r = -e_i/3$ and that $e_s = 0$.

If the original pulse sent out on the transmission line has a magnitude of six volts, and assuming no attenuation or distortion of the pulse in its travel, the wave impinging upon the load has a magnitude of six volts. As a result the reflected voltage wave e_r has a value of -2 volts. The picture seen on the screen of an oscilloscope connected across the load resistor R_L is that of a single resultant pulse with an amplitude of $e_L = 6 - 2 = 4$ volts.

A simple calculation reveals that the polarity of the resultant pulse at the receiving end of the line is the same as that of the incident pulse irrespective of the magnitude of R_L, according to the equation

$$e_L = e_i + e_r = e_i\,(2R_L)/(R_L + Z_0) \quad (6)$$

Thus, it is evident that the pulse viewed at the receiving end is always of the same polarity as the incident pulse and has a magnitude in the range from zero to 2 e_i, depending upon the relative values of R_L and Z_0.

It is apparent that the reflected voltage wave of the preceding example, $e_r = -2$ volts, travels back to the sending end of the line. There it encounters a resistance $R_G = Z_0$ which completely absorbs the returning wave.

The picture viewed on an oscilloscope connected across the sending end of the line consists of the original six-volt positive pulse, and a two-volt negative pulse displaced from the initial pulse by a time interval $T = 2S/V$. Of course, if R_G were not equal to Z_0, reflection would take place at the sending-end as well as at the load end of the line, and many reflected pulses would appear on the oscilloscope screen.

Distortion of Waves

There is always a finite amount of attenuation of a wave on a transmission line due principally to the effective resistance R of the conductors and to the conductance G between the wires. If the line con-

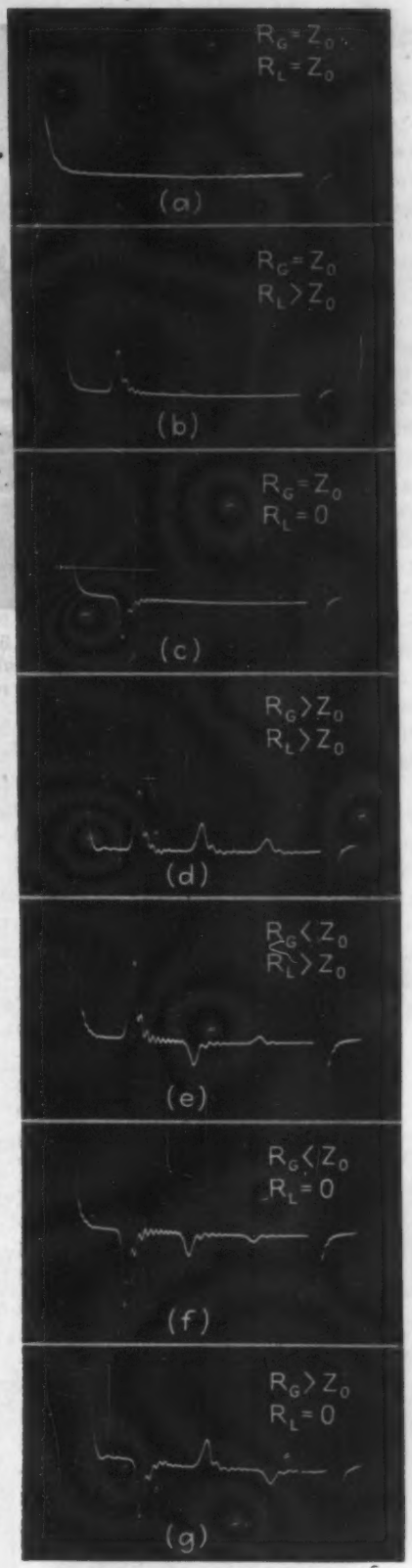
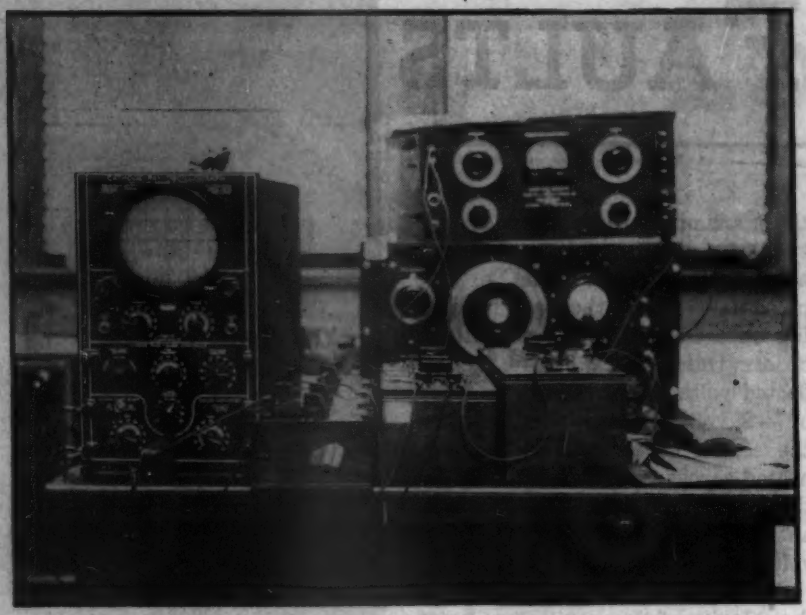


FIG. 2—Oscillograms illustrating the reflection phenomena on an artificial transmission line. In (a) where both ends of the line are terminated in the line's characteristic impedance there are no reflections. In (b) and (c) the sending end of the line is terminated in its characteristic impedance. The others have repeated reflections from both ends



Equipment used to test transmission lines by the pulse method. The output of the square-wave generator (top right) is differentiated, the resulting pulse is fed to the line, and reflected pulses are observed on oscilloscope

stants are so proportioned that RC equals GL, the line is distortionless. A wave travelling on this line is attenuated as it moves along the line, but it retains its original shape as a function of time as viewed at any point along the line.

Laboratory Arrangement

The constants of the usual power and telephone transmission lines do not satisfy the condition for a distortionless line. The type of wave distortion to be expected on these lines is a rounding of sharp points on the wave and a sloping-back of the wave front.[4] From the Fourier viewpoint, the component frequencies in a recurrent pulse travel with different phase velocities and undergo different degrees of attenuation, with the result that the pulse is distorted. This type of distortion is present in the photographs described later. Additional distortion in the form of a damped oscillation trailing each pulse is apparent in the photographs taken on an artificial lumped constant line. This transient oscillatory distortion of pulses is absent on all observations made on an actual open-wire line where the impedance is uniformly distributed along the line.

The artificial laboratory line used to check the pulse technique consists of 25 balanced-H sections of inductance and capacitance, and simulates a non-loaded open-wire line of No. 12 wire approximately 200 miles long. The characteristic impedance of the line measured at 800 cps is $669 - j19$ ohms. The line is reasonably well terminated over a wide band of frequencies by a resistance of 670 ohms.

The laboratory arrangement used to obtain the photographs is shown in Fig. 1(b). The sending-end impedance R_G consists of R_S in series with the pulse generator impedance R_P. The square-wave generator internal impedance is large compared to R_P. It is desirable to make R_P much smaller than Z_0 in order that R_G will be essentially equal to R_S. The sending-end impedance is then conveniently changed simply by changing the value of the resistor R_S.

The pulse signal is obtained by differentiating a square wave using the coupling capacitor C and the resistor R_P. Thus, the fundamental frequency of the pulse wave is the same as that of the square wave, and the pulse width is varied by changing the RC values of the differentiating circuit. Other types of pulse generators are suitable.

Laboratory Photographs

The series of photographs in Fig. 2 demonstrate clearly the behavior of the pulse wave on a transmission line. In examining the photographs, it is well to remember that the oscilloscope connected across the sending end of the line gives a picture of the resultant pulse at the sending end, and that this resultant pulse is of the same polarity as the returning pulse incident on the generator. The duration of the traces of Fig. 2 is 1/120 second, and therefore a half cycle of a differentiated 60-cycle square wave is shown.

In Fig. 2(a) no reflected pulse is present, because the line is properly terminated in its surge impedance. Only one reflected pulse is present in Fig. 2(b) and in Fig. 2(c), as the sending-end impedance is equal to Z_0 so that the returned pulse is absorbed by this impedance. In the remainder of the photographs, three reflected pulses appear. Note that the pulses are spaced at equal intervals representing the time required for the pulse wave to travel twice the length of the transmission line.

The following detailed explanation of the excursions of the pulse shown in the oscillogram of Fig. 2(g) assists in an understanding of the other oscillograms. The initial positive pulse travels the length of the line and impinges upon a short-circuit at the receiving end of the line. Hence, the first reflected pulse is of negative polarity and travels back to the sending end where it is seen as a downward pulse. This first-returning wave encounters a sending-end impedance which is greater than Z_0, and therefore a negative reflected pulse is sent out on the line. This negative pulse is reversed in polarity at the load end of the line, with the result that it is seen as a positive pulse on its second return to the sending end. From here on, the previously-

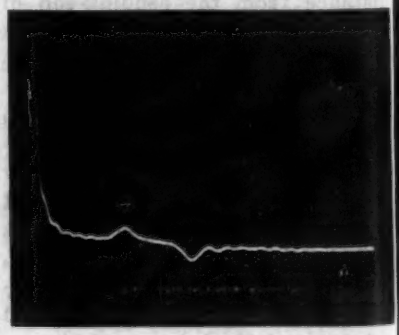


FIG. 3—Irregularities on a lumped-constant artificial line are quickly determined by their oscilloscopic trace

described action takes place so that alternate pulses are of like polarity.

The photograph in Fig. 3 shows the effect of two different types of discontinuities simultaneously present on the transmission line with both the sending-end and load resistances equal to the line surge impedance. The positive pulse is caused by a 74-ohm resistor inserted in series with each side of the line at the 13th section, while the negative reflected pulse is caused by a 2,500-ohm resistor shunted across the line at the 22nd section. The multiple reflections which occur between the two discontinuities are distorted and of minor magnitude, hence they are not visible in the photographs.

Convenient lattice diagrams of great assistance in the calculation of the reflections to be expected at any point and at any instant of time on a transmission line containing several discontinuities are described by Bewley.[5]

The length of a transmission line, or the distance to a discontinuity, is easily determined by measuring the time interval between the initial pulse and the particular reflected pulse in question. This measurement is made by any of the standard methods. The most primitive method is to measure both the length of the entire trace as well as the length from the initial pulse to the reflected pulse with a rule, or with the cross-section coordinates on the oscilloscope screen.

Information for a calculation of this type is presented in Fig. 4. The fundamental frequency is 600 cps. The pulse is traveling on an open-wire line and therefore its velocity V is very nearly 180,000 miles per second. From the figure, T is measured to be $(2/3)T_1 = (2/3)(1/2F) = 1/1800$ second. Therefore the length of the line S equals $(1/2)\ VT = (1/2)\ (18 \times 10^4)\ (1/18 \times 10^4) = 50$ miles.

More rapid methods of measuring the distance to a discontinuity involve the use of a Z-axis timing signal, or a timing signal flashed over the pulse trace by an electronic switch.

Tests on an Open-Wire Line

Through the courtesy of Mr. L. C. Bomar of the Southern Natural Gas Company, the writer had the opportunity to check the pulse technique on an open-wire line 146 miles long paralleling a gas pipeline from Atlanta to Birmingham. Figure 5 is a pulse panorama of the entire line. The last reflected pulse of positive polarity is caused by the Birmingham end of the line, where the line is terminated in a 2500-ohm relay. The remainder of the reflections are due to similar relays shunted across the line at various stations, and due to several short lengths of cable circuit interposed in the line.

Figure 6 shows the reflected pulse obtained upon open-circuiting the line at a point 80 miles from the sending end. When the line is short-circuited at the same point, the identical pulse appears but with a negative polarity.

Conclusion

The pulse technique appears promising as a method of measuring the distance to a discontinuity on a transmission line. If the normal pulse history of a particular line is photographically recorded, any new discontinuity can be readily detected by placing the negative of the photograph over the oscilloscope screen.

An advantage of the pulse technique over other methods of measuring the distance to discontinuities is that a complete instantaneous picture of the entire line is revealed at a glance. In addition, the nature of the discontinuity is immediately apparent.

Possible applications of the pulse technique are: (1) To measure the distance to an open or short-circuit on transmission lines. (2) To measure the distance to irregularities on lines. (3) To measure the velocity of propagation of pulse signals on transmission lines of known length. (4) To rapidly check the value of the characteristic impedance of a transmission line, or to determine whether or not a line is terminated in its characteristic impedance. (5) To continuously monitor a line to determine where and when a break occurs during inclement weather, or during periods when sabotage is expected.

A fruitful field for research exists in the use of pulse-modulated carriers as a test for discontinuities on transmission lines. The writer believes that the pulse technique can be advantageously used to locate discontinuities on telephone, telegraph, and power lines in areas stricken by wind and ice storms.

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(3) Breit, G. and Tuve, M. A., A Test of the Existence of the Conducting Layer, *Phys. Rev.*, 28, p. 554, Sept. 1926.
(4) Skilling, H. H., "Transient Electric Currents", McGraw-Hill Book Co., Inc., New York, 1937.
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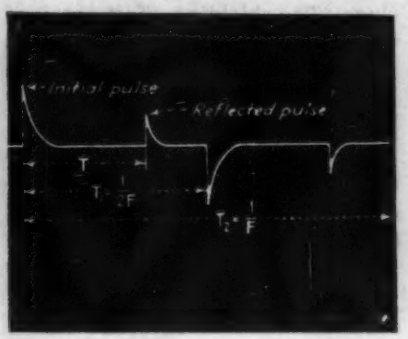

FIG. 4—The length of line is found by correlating an oscilloscopic trace with the fundamental pulse frequency

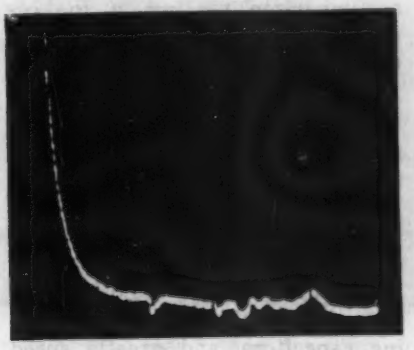

FIG. 5—This panoramic pulse view taken from Atlanta shows the Atlanta-Birmingham telephone line in its normal state

FIG. 6—An open circuit 80 miles from Atlanta on the line shown in Fig. 5 produces the positive pulse shown here

CAPACITOR-MATCHING

Construction and calibration of a direct-reading beat-frequency oscillator for use in production matching of variable capacitors. Principle involves comparing frequencies of two duplicate oscillators, one containing the standard capacitor, the other containing the production capacitor

PRECISION calibrating and matching on a mass-production basis is one of the greatest problems in the manufacture of variable capacitors. The trend in recent years toward higher frequencies, compactness, and higher standards in receiver design has resulted in corresponding limitations in capacitor tolerances.

Any limitations on the tolerance of the capacitance curve require closer control throughout the stages of production. Today the tolerances have approached such narrow limits that the manufacturer has to hold to rigid standards on the mechanical structure in order to approach as closely as possible the specified capacitance curve. Only when great mechanical accuracy exists can the capacitor be calibrated and matched with any success.

Calibration Techniques

Calibration of a capacitor is a tedious job, whether for experimental work or for a production run. The term calibration as used in the variable-capacitor field applies to adjusting the capacitance of the unit to the required capacitance curve by bending serrations on the rotor plates of a single-section variable capacitor, or in the case of a ganged capacitor, the one section which is generally used to tune an oscillator.

Calibrating in the past was accomplished by taking readings at specified degrees of rotation and comparing them to the original curve in order to determine the necessary loss or gain in capacitance, and then bending the serration at each reading to produce the required results. The operation was speeded up by the use of a simple beat-frequency oscillator and a standard capacitor adjusted to the desired curve. This method, although much faster, was still handicapped because of the necessity for continuously switching between the standard and the capacitor being calibrated.

Matching a ganged capacitor which consists of adjusting the remaining sections to conform to the calibrated section was handled in the same manner. It will readily be seen that if the tolerances were held to comparatively small limits, 0.5 $\mu\mu f$ or smaller, a continual switching between the capacitor being calibrated and the standard would be necessary.

To solve this problem, Hammarlund engineers decided to limit the switching to an absolute minimum. To do this, of course, means taking a comparison reading of the capacitance directly from a dial on the test instrument. With this object in mind, a search was made for a design that would answer the purpose.

Improved Method

It was discovered that with some modification, existing beat-frequency oscillators could be made to serve for calibrating and matching capacitors, and greatly speed production over existing methods.

In order to check by direct comparison it is necessary to have two variable oscillator circuits beating against each other. The final circuit is shown in the schematic diagram, Fig. 1. The standard capacitor C_{s1} is placed across one oscillator, and the capacitor to be calibrated (C_{s2}) across the other oscillator. Both capacitors are set to minimum capacitance and locked to a single shaft as shown in Fig. 2. By means of trimming capacitors C_3 and C_4 the oscillators are brought to zero beat as indicated by a null reading of meter M. The capacitor under test and the standard are then rotated together and the oscillators held at zero beat by means of the calibrated capacitor C_1. The change in C_1 necessary to accomplish this is a direct indication of the difference between the curve of the capacitor being calibrated and the required capacitance curve.

Design of Tester

The inductors L_1 and L_2 are variable, having movable iron core slugs. The shielding effect obtained with L_2 mounted above the chassis and as far away from L_1 as possible, is sufficient for all practical purposes. C_1 is a straight-line capacitor whose value depends on the capacitance to be covered in the tolerance specifications for the required capacitor curve. C_1 should be sufficiently rugged mechanically to withstand constant use during production tests. It was found that a total value of approximately 15 $\mu\mu f$ gave the required swing of 10 $\mu\mu f$ without using the full 180 deg

OSCILLATOR

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swing of the capacitor, thereby using only the linear portion of the capacitance curve. A value of 5 $\mu\mu$f each side of zero gave sufficient capacitance variation so that all tolerances could be met. C_3 and C_4 are trimming capacitors used to bring the two oscillators to zero beat. C_3 is used for making coarse adjustment in trimming whereas C_4 is used for final adjustments. Consequently, C_4 has a smaller capacitance than C_3. These trimmers are connected in parallel with one oscillator circuit to correct for small differences in capacitance that might exist between the capacitors under test due to their minimum capacitance and the leads.

C_5 and C_6 are loading capacitors which give a total base capacitance in each oscillator circuit of approximately 2000 $\mu\mu$f. They are added so that the frequency of the oscillator circuits would be relatively low, approximately 400 kc without external load, thereby minimizing the inductive effects of test leads. Care must be taken to keep the values of C_5 and C_6 as nearly alike as possible so that trouble will not be encountered in balancing the inductances L_1 and L_2.

The capacitors C_7 and C_8 couple the oscillator plates to the detector. These capacitors should have relatively small values (in the order of a few $\mu\mu$f) so that the coupling between the two oscillators will not be great enough to cause the oscillators to lock. They should be as closely matched as possible.

Construction of Tester

Both oscillator circuits must be kept as nearly alike as possible in the values of their component parts as well as in their wiring. Any great differences may cause serious unbalance between the circuits. All precautions should be taken in the matter of placement of parts in order that coupling effects will be a minimum. If too much coupling is present the lock-in between the oscillators will be such as to decrease the sensitivity of C_1. Either the capacitor under calibration will appear to track perfectly because the two oscillators lock, producing a permanent null indication, or the change in C_1 necessary to upset the balance will be abnormally large because of the tendency of the oscillators to remain at zero beat until tuned to widely different frequencies.

The mechanical structure of the beat-frequency oscillator must be sufficiently rugged so that momentary strains set up by external sources will not throw the instrument off calibration due to variations in the inductances. All points of ground contact in the wiring as

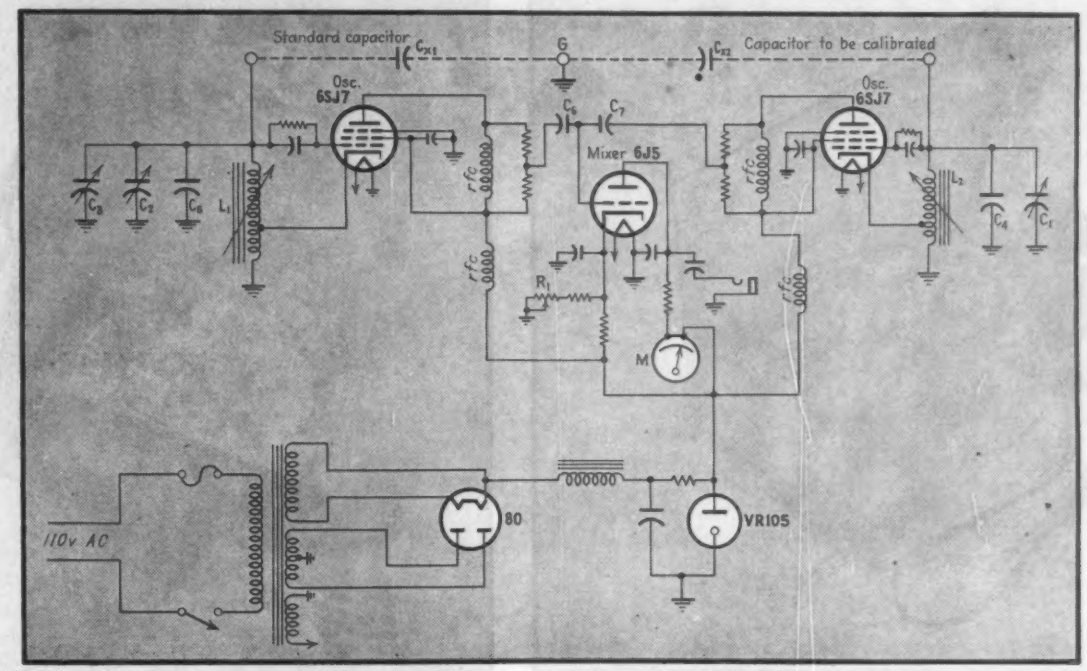


FIG. 1—Circuit diagram of the capacitor-matching oscillator. The outputs of the two oscillators are heterodyned in the 6J5. When both frequencies are the same the meter *M* gives a null indication. If the capacitor under test differs slightly from the standard, capacitor C_1 in the oscillator containing the unknown capacitor is adjusted to give a null on the meter. This change in C_1 gives directly the error in the unknown capacitor

well as in the fastenings of the dust cover and bottom plates should be made as secure as possible in order to overcome any difficulties from this source.

Calibration of Tester

Before the beat-frequency oscillator is calibrated, a simple balancing set-up will be required. The set-up consists of two fixed capacitors which have three or four times the maximum capacitance of the capacitors that will be calibrated in production. One should have a capacitance of from 1 to 2 $\mu\mu f$ greater than the other. The use of a much greater capacitance for balancing, over the values to be used during the production test, proportionately reduces the final errors.

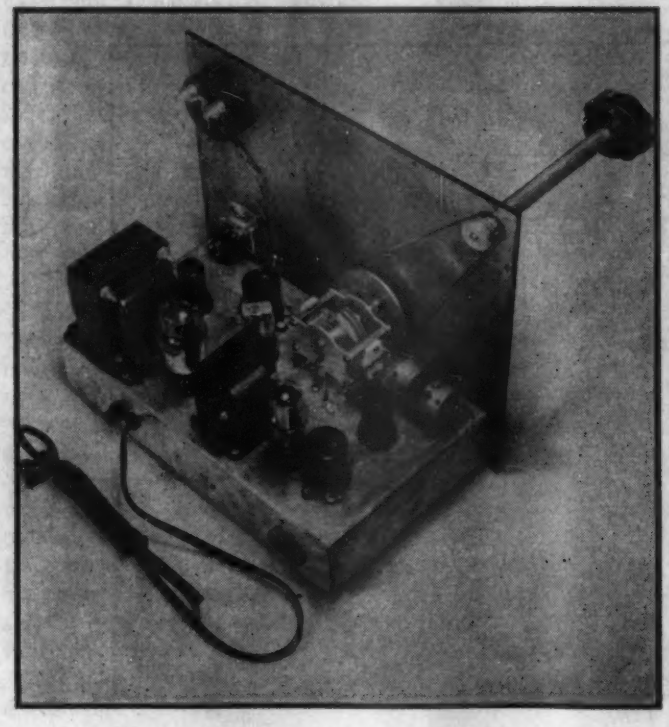
The two fixed capacitors should be tied together and the common point fastened to the binding post at G on the front panel. The remaining terminal of the standard capacitor is fastened to C_{X1}, and the terminal of the other capacitor is fastened to C_{X2}, as shown in Fig. 1. The leads fastened to C_{X1} and C_{X2} should be checked for length and symmetry. When the balancing set-up has been made as symmetrical as possible it is removed from the binding posts and placed to one side until some preliminary adjustments are made, prior to final balancing.

The next step is to set the movable slug in L_2, which is above the chassis. This is done by backing it out as far as it will go and then screwing it in approximately three or four turns. The dust cover is then put in place and securely fastened, using lock-washers under the screw heads to give good ground contact and rigidity. The variable potentiometer R_1 is of sufficient resistance to cause a full-scale deflection of meter M, which is preferably a 200-microampere meter. R_1 is set so that the meter shows half-scale deflection. The bottom plate is then placed in position and fastened securely.

The oscillator is now ready to be balanced. The pointer of C_1 is set in the center of the dial, where a reference line is drawn. C_2 and C_3 are set so that their rotor plates are half-way out of mesh. L_1 is then adjusted by means of the movable slug until the meter deflection takes the lowest dip. A pair of headphones plugged into the phone jack will come in very handy to listen for the decrease of the beat pitch and to detect the null.

Unique Balancing Technique

The fixed capacitor set-up that was made previously is now fastened between C_{X1} and G and C_{X2}. C_1 is then turned to the right or left, as the case may be, until the meter indicates the null point and the distance of the pointer on C_1 from the reference line measured. Here use is made of the 1 to 2-$\mu\mu f$ difference between the two capacitors of the balancing set-up. Remove the set-up from the test terminals and reverse its position. The lead formerly connected to C_{X1} should now be connected to C_{X2} and vice versa. Measure the deviation of C_1 as outlined above. The inductance value of L_1 is then adjusted by means of its movable slug until, with the oscillators balanced, the pointer on C_1 is the same distance from the center line on the one side as it was on the other before the test set-up was reversed. Note that it is necessary to re-bal-



Chassis assembly, showing the iron-core inductor of one oscillator at the right on top of the chassis, and the straight-line error-measuring capacitor at the center

Under-chassis wiring, showing the similarity between the two oscillator circuit lay-outs. The balancing capacitors, C_2 and C_3, are at the top in this view

ance the equipment each time the inductance value is changed, by means of C_2 or C_3 with the capacitor set-up disconnected.

Some means should be made for locking the inductor adjustment once balance is reached. The headphones prove very useful in checking the unbalance between the oscillators because occasionally the unbalance is of such a nature that no deflection is shown on the meter, the capacitance of C_1 at the moment being either too great or not great enough. An increase or decrease in the frequency of the audio signal as heard over the earphones is noted when C_1 is rotated. The movable slug of the inductor is then adjusted so that there is a constant decrease in the frequency of the signal until with C_1 set somewhere near the reference point a null is obtained. The final balance can be made without the headset inasmuch as the balance between oscillator circuits has been determined to fall on the dial of C_1.

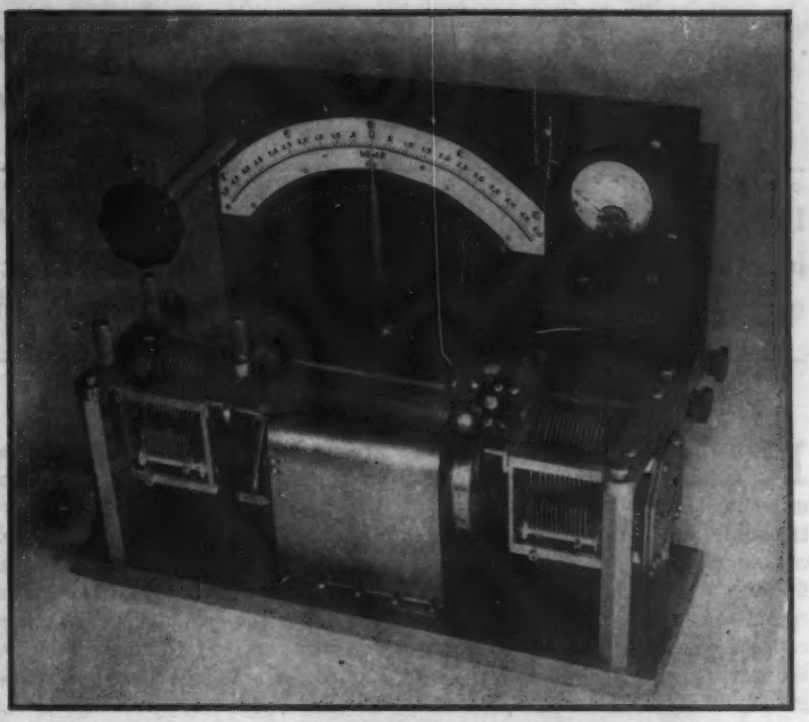


FIG. 2—The production capacitor is ganged to the standard capacitor, and connections are made to the terminal posts on the matching oscillator. The two capacitors are rotated, and the oscillators are kept in balance (as indicated by the meter) by adjusting the straight-line capacitor. The error between the unknown and the standard capacitor is read directly from the scale. The controls at the right balance the oscillators before measurements are made. This capacitor-matching oscillator was designed and built in the Hammarlund Laboratories

Dial Calibration

The beat frequency oscillator should be perfectly balanced with the pointer of C_1 in the center of the dial. However, there are two values which will have to be precisely determined in order to calibrate the instrument accurately. These values are the base frequency and base capacitance with the instrument set and balanced at the reference point. These values need only be determined for the oscillator circuit in which C_1 is included, because the other oscillator circuit is balanced to it. The base frequency can be determined by any of the standard frequency-measuring methods.

Substitution Determination of Capacitance

The base capacitance can be determined by selecting two silvered mica capacitors whose capacitance values differ from each other by at least 1000 $\mu\mu$f. These capacitors should be measured accurately and marked and their readings recorded. They are then fastened separately across the C_{x3} and G terminals, and the frequency produced by the addition of each capacitor is determined by the same method used in determining the base frequency. Then by use of the two-frequency method the base capacitance can be calculated from the following equations:

C_x = base capacitance to be found
f_1 = the higher frequency in kc
f_2 = the lower frequency in kc
C_{v1} = the capacitance added to produce f_1
C_{v2} = the capacitance added to produce f_2

$$\left[\frac{f_1}{f_2}\right]^2 = \frac{C_x + C_{v2}}{C_x + C_{v1}} = FR^2$$

Writing $\left[\frac{f_1}{f_2}\right]^2$ as the frequency ratio, FR^2, the following formula is derived:

$$C_x = \frac{C_{v2} - FR^2 C_{v1}}{FR^2 - 1}$$

The base frequency and base capacitance for the oscillator circuit whose tuning capacitor is to be calibrated are now known. When the pointer of C_1 is set on the reference line the equipment should be in balance.

Calibration of C_1

A good audio oscillator and an oscilloscope will be needed to do the final calibrating. The audio signal from the beat-frequency oscillator can be picked up from the phone jack.

The method of calibrating C_1 is to compare the beat frequency of the matching oscillator to the frequency of an audio oscillator by means of the oscilloscope and Lissajous figures. The minimum change in frequency which can be measured in this manner depends on the calibration and stability of the audio oscillator, but this consideration need not limit the size of divisions to which the scale of C_1 can be calibrated. As was stated previously, the capacitor C_1 has a straight-line characteristic, and is only used over the central portion of its range where its linearity is highly reliable. If in addition it has a substantial air gap, it can be calibrated every 0.5 $\mu\mu$f, for example, and subdivisions every 0.1 $\mu\mu$f added. It was found at Hammarlund that by using this method the errors were so small as to be negligible. With C_1 calibrated, the capacitor-matching oscillator is ready for use.

ARMY RADIO D-F

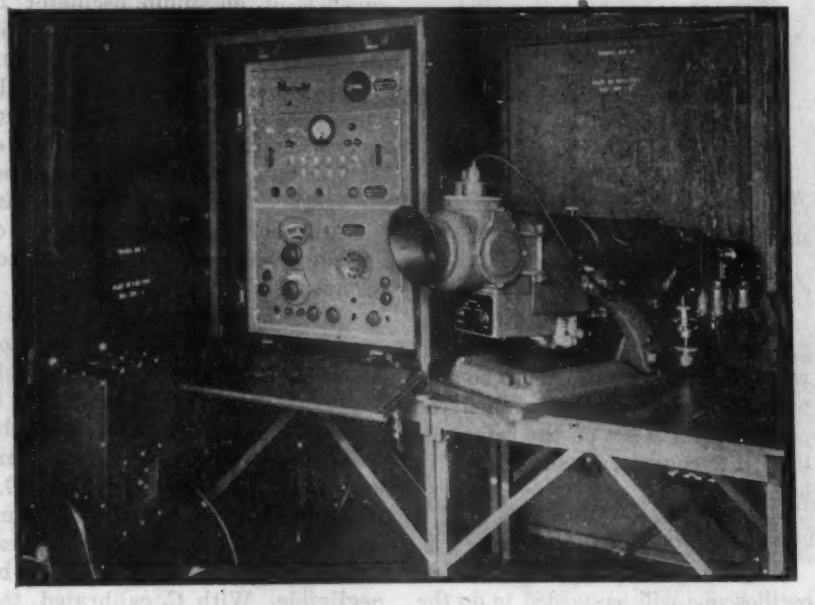
Description of SCR-291 radio direction finder, used by AACS to provide accurate bearings for military pilots on world-wide air routes. Indications appear on a cathode-ray tube screen. Operating procedures and factors affecting choice of sites are covered

RADIO DIRECTION-FINDING is a method employed to determine in degrees the direction of a transmitting agent, such as an off-course airplane, from a direction-finder station. Such operation is accomplished by the use of a receiver coupled to a specialized type of antenna with which the horizontal angle of incidence of incoming signals from a remote transmitter can be found relative to some predetermined standard, usually true or magnetic North.

Because the individual d-f station is capable of obtaining directive bearings only, a number of stations, properly located with respect to the distances over which operation is desired, can be grouped together in a d-f net for the purpose of determining geographical positions. These positions, or "fixes" as they are commonly called, are determined by the central or control station of the net. Individual bearings are obtained from each satellite station and plotted on a chart. Proper evaluation of the point of intersection of the collected bearings results in the fix, which may be reported back to the original transmitting agent or to rescue forces, depending on the circumstance.

The direction finder is a natural outgrowth of radio development and radio control. For many years surface vessels and aircraft controlled their movements visually, as no other method was available. Visual control, however, is obviously limited by the surrounding terrain, the prevailing atmospheric conditions, the spherical construction of the earth's surface, and many other factors that tend to restrict its usefulness to the immediate surroundings of the observer. With the advent of wireless communications, these limitations were greatly minimized, and the use of direction finding became increasingly important.

This discussion is concerned chiefly with the use of direction finding as a radio navigational aid operating in the field of military aviation. While the direction finder is not infallible, nevertheless it has proved itself a vital element in the safe conduct of airplanes over our farflung Army Airways.



Direction indicator is at the right in this interior view of an SCR-291 direction-finder shack. Receiver, control panel, and telephone panel are rack-mounted at the left

The Actual Equipment

There are many types of d-f equipment in use throughout the world—most of them employing a loop or Adcock-type antenna array. Generally speaking, the choice of equipment is determined by the operating characteristics desired and the circumstances and conditions peculiar to the sphere of operation. Surface vessels, for example, ordinarily make use of a direction finder whose antenna is of modified loop design, whereas shore-based units usually employ an Adcock arrangement.

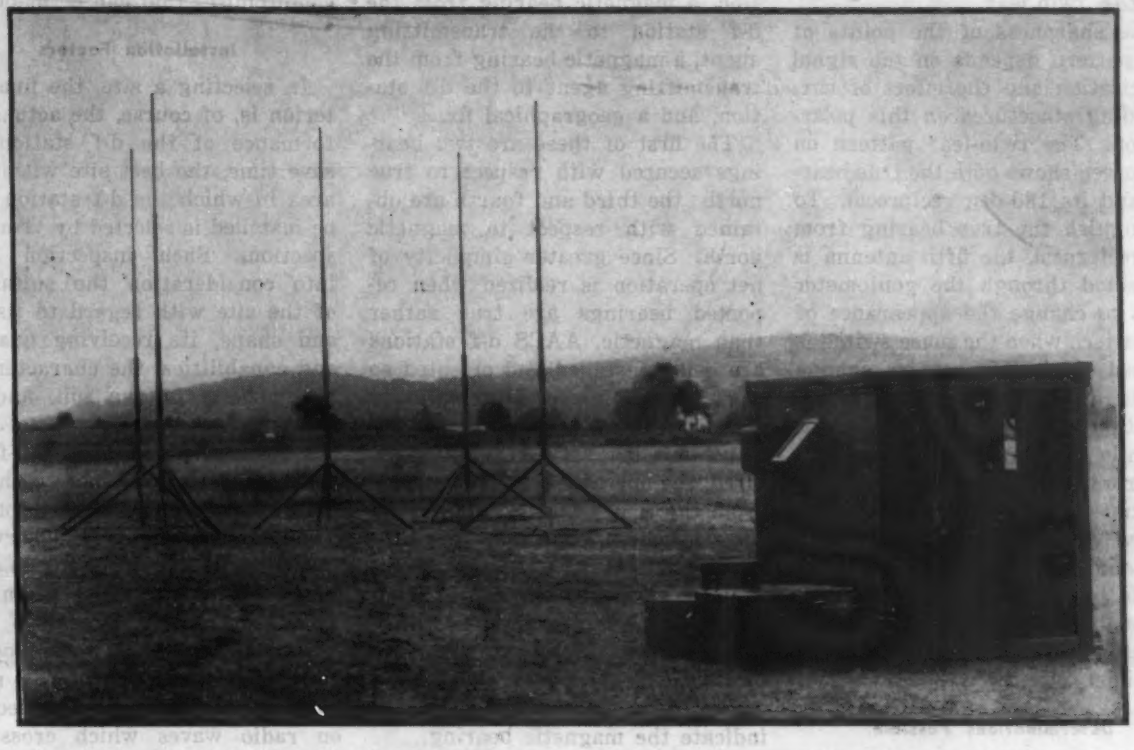
As Army aircraft radio operation is normally confined to a frequency range between 2 and 12.5 Mc, d-f equipment must be capable of supplying continuous bearing coverage within these limits.

Another requirement of satisfactory equipment is the need for obtaining bearings rapidly and with a minimum of the human element involved. Then, too, there are definite advantages in semi-portable equipment which can be installed quickly and disassembled with relative ease.

A direction finder manufactured by Federal Telephone and Radio

NETWORKS

By Major Giltner Twist, A.C.
Army Airways Communications System
Asheville, N. C.



Complete installation of direction-finding station. It can be disassembled for air transportation in 23 chests and crates. To the left of the operating shelter are the five masts of the modified U-Adcock antenna, each with its ground mat below

Corp. is used by the AACS. It possesses desirable features for this operation. It is semi-portable and employs a U-Adcock antenna designed for fixed station use. A cathode-ray tube and a motor-driven goniometer provide instantaneous bearings with a minimum of the operator's time and attention.

The set is built to withstand the effects of vibration, concussion from gunfire, and general rough use. When used for direction finding, the equipment is continuously variable over a frequency range of from 2 to 10 Mc, while its average sensitivity is approximately 5 to 15 microvolts per meter for a ±2-deg bearing reliability. The indications of the d-f set are continuous and automatic—automatic in the sense that if the direction of the received signal should shift with respect to the azimuth, the indication on the cathode-ray screen would shift accordingly without further tuning on the part of the operator.

Through the operation of the goniometer, the cathode-ray tube, and their associated electrical network, a visual trace pattern is projected on the face of the tube. The operator tunes the signal in, reads the two directions indicated, determines the true direction by pressing the sense switch, and reports his findings. As the signal is reproduced in visual form, all searching for aural nulls is eliminated. The operator can read the signal as he takes the bearing, and thus determines the type of transmission, the strength of the signal, the existing noise level, and numerous other wave characteristics common to radio transmission.

The modified U-Adcock-type antenna used with the set consists of five antenna masts. Four are installed on the corners of a square measuring approximately 25 ft. on each side, and provide two directional pairs of antennas. The fifth mast is placed on the intersection of the diagonals between the corner masts. The five antennas are connected to the goniometer by phase-inverter coupling units and r-f transmission lines. Each phase-inverter coupling unit is installed between the twin coaxial transmission lines and the antenna to combine impedance matching and aperiodic operation. It thus provides a uniform transfer of energy throughout the entire frequency range of the equipment with minimum attenuation from the long transmission lines.

The goniometer is a series of r-f transformers which eliminate the necessity for revolving the antenna. It is composed of six specially designed coils, the coils being wound at critical angles on a special stator. The coils are connected to the two pairs of balanced coaxial transmission lines, which in turn are connected to the antenna.

The coils, arranged so as to eliminate the need for slip rings and brushes, which are often delicate and troublesome, operate in conjunction with the motor-driven rotor to provide the same effect as

that obtained by rotating the antennas manually. With the signal properly tuned and the sensitivity adjusted, there appears on the cathode-ray screen a pattern similar to a twin leaf.

The sharpness of the points of this pattern depends on the signal polarization and the effect of surrounding structures on this polarization. The twin-leaf pattern on the screen shows both the true bearing and its 180-deg reciprocal. To distinguish the true bearing from the reciprocal, the fifth antenna is connected through the goniometer so as to change the appearance of the pattern when the sense switch is pressed. It is this pattern change which indicates the true or actual direction of the transmitting agent.

While this equipment is subject to errors resulting from conditions of atmosphere and terrain, it has proved quite satisfactory from a mechanical point of view, and is so simple in operation as to perform reasonably accurately even when operated by relatively inexperienced personnel.

Determinations Possible

The operations of a d-f system are usually such as to provide one or more of the five following types of bearing: A true bearing from the d-f station to the transmitting agent, a true bearing from the transmitting agent to the d-f station, a magnetic bearing from the d-f station to the transmitting agent, a magnetic bearing from the transmitting agent to the d-f station, and a geographical fix.

The first of these are two bearings secured with respect to true north; the third and fourth are obtained with respect to magnetic north. Since greater simplicity of net operation is realized when reported bearings are true rather than magnetic, AACS d-f stations are being installed and oriented so that the equipment automatically furnishes a true bearing.

When a magnetic bearing is desired, the operator must compute it from the true bearing obtained by the equipment. In order to guard against mistakes on the part of operating personnel, there is being developed a simple computer which, once it has been set to the magnetic declination existing at the station where it is used, will automatically indicate the magnetic bearing.

The ideal site for a direction finder would be the center of a uniform plane of good conductivity. This type is rarely found in practice, but good operation can be obtained from the average site if the operator is acquainted with the compromises that can be made.

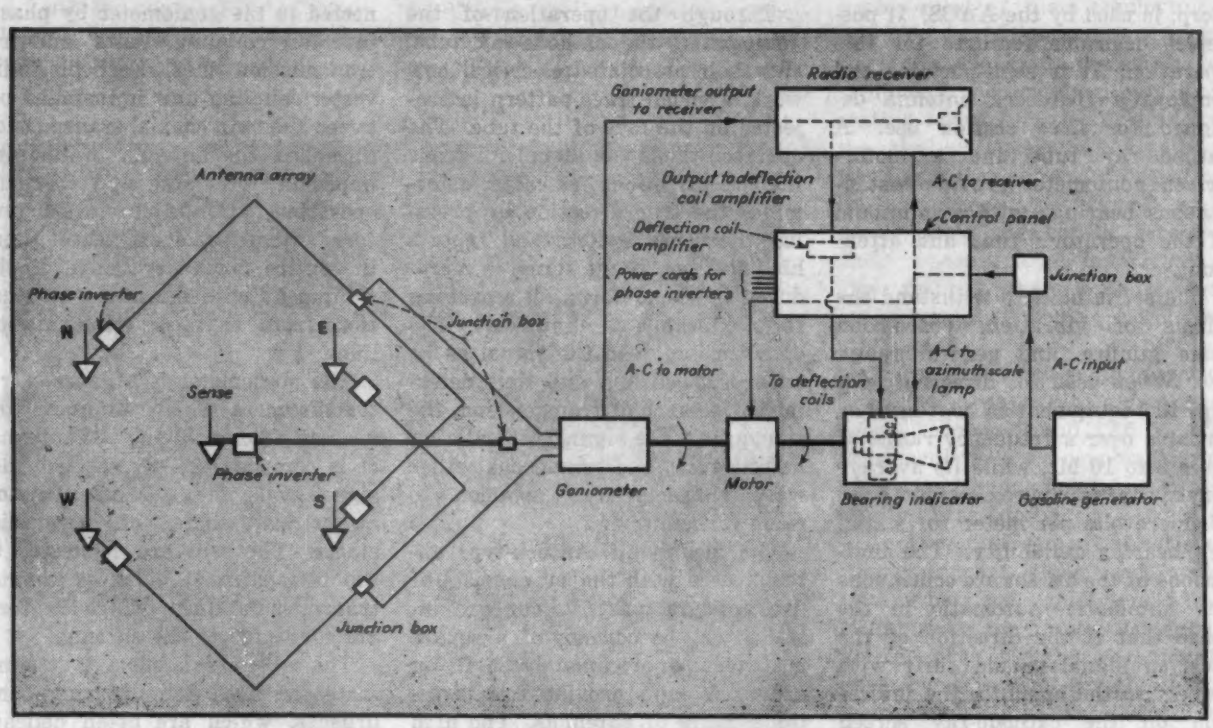
Installation Factors

In selecting a site, the final criterion is, of course, the actual performance of the d-f station. To save time, the best site within the area in which the d-f station is to be installed is selected by visual inspection. Such inspection takes into consideration the suitability of the site with regard to its size and shape, its receiving qualities and capabilities, the character and homogeneity of the soil, and the signal-to-noise level.

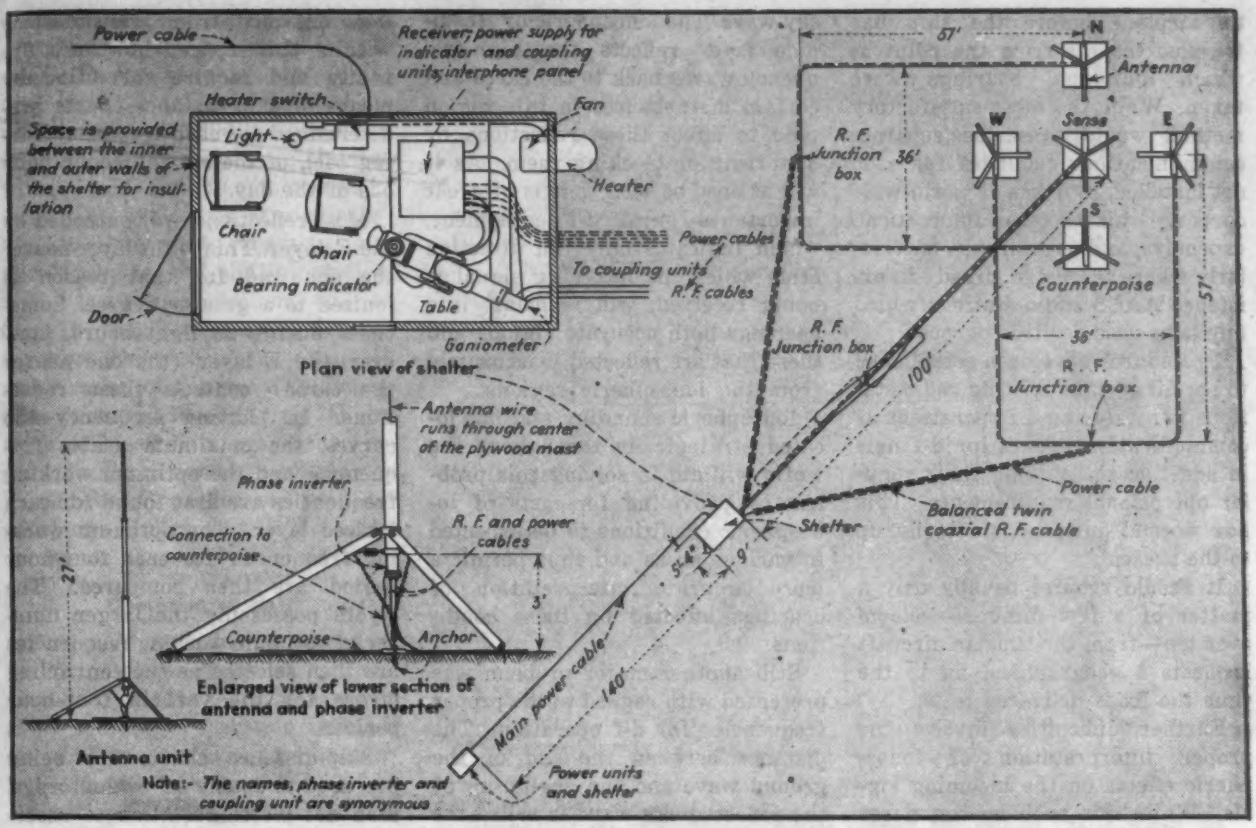
Proper selection of the d-f site is of utmost importance to the accurate operation of the equipment. The following notes will serve to illustrate the types of serious error that may result under certain conditions:

Coastal Effects. A station located a few miles inland will find unreliable such bearings as are secured on radio waves which cross the coast line at acute angles.

Topographical Features. Hills or



Functional diagram shows connections between parts of AACS direction-finder station. Signals from the antenna array pass through the goniometer to the receiver and from there to the deflection coils and the indicator which provides the bearing required



Plan of direction-finder site, giving detailed disposition of components with dimensions

mountains adjacent to d-f stations often produce constant or fluctuating bearing errors. Sites within one wavelength of cliffs or large rocky out-croppings will render bearings inaccurate with respect to wave-length, angle of elevation, and azimuth.

Adjacent Structures. Large buildings, overhead wires, metallic fences, and trees can have a very appreciable effect on the accuracy of d-f bearings. Every effort is made to install the equipment such a distance from obstructions of this nature as to avoid the possibility of error.

Ground Characteristics. A uniform, highly-conductive soil acts as a mirror for radio waves, thus attenuating the abnormally polarized components of the wave and preventing path distortion of the incoming wave. For this reason flat, salt marshland is far more desirable for d-f purposes than other types of soil. Practical difficulties normally encountered in such areas, however, usually preclude their use as d-f sites. Rocky or sandy soil is most unsuitable for d-f work by reason of changes and non-homogeneity in its electrical conductivity.

In addition it frequently has been found that sites which visual inspection would indicate to be inadequate furnish quite satisfactory bearings, and that sites which seem to be ideal produce large bearing errors. This is due to a number of technical considerations which are too involved to be discussed here.

After the equipment is installed, it is calibrated before being put into regular operation. This calibration is effected by means of either a target transmitter, distant fixed radio stations, aircraft, or any combination of the three.

The equipment at AACS d-f stations is calibrated by having an airplane circle the set at a distance of approximately 10 miles. The bearing of the airplane is observed visually through a surveyor's transit or a theodolite, and a d-f bearing is obtained at the same time. This process is completed at 4 or 5 degree intervals for 360 degrees of the compass, after which an error curve is prepared from the differences noted in the two sets of bearings.

It is readily apparent that the proper selection of sites constitutes a most serious problem for the AACS. Its stations must be situated along the air routes—in mountainous areas, or sandy beaches, in ice-covered regions, and desert expanses. Operating personnel often find it necessary to install and disassemble d-f equipment many times in an area before a satisfactory site can be found.

Scope of Operation

As the AAF air routes encircle the world, the AACS expands with them. These routes include long flights over both tropical and artic oceans, as well as overland flights through dangerous jungle and mountainous countries.

Installation of the individual stations has progressed to such a point that in the very near future an army pilot will be able to fly almost anywhere in the world and expect a reply to his request for a bearing.

One of the major problems concerns the communications system to be employed for collecting the individual bearings for plotting purposes. It goes without saying that such a system must be rapid and efficient if it is to provide a fix to

an airplane before the ship has traveled too far from the point at which individual bearings were taken. While the most satisfactory method would prescribe separate communications facilities for each net installed, in terms of world-wide coverage this becomes impractical, expensive, and undesirable, particularly where there are already in existence AACS radio stations which might be used for this purpose.

Procedures have been established to permit certain existing radio stations to act during d-f operations as communication agents for d-f nets in addition to fulfilling their regular operational requirements. This has worked quite satisfactorily up to the present.

It should require usually only a matter of a few minutes—seldom over ten—from the time an aircraft requests a geographical fix to the time the fix is delivered to it.

Further difficulties involve the proper interpretation of ionospheric effects on the incoming signals. While this problem can never be completely solved, action has been initiated which will lessen these effects.

The program planned by the AACS is concerned primarily with long-range operation employing the sky wave. The ionospheric or Heaviside layer reflects the high-frequency waves back to the earth and certain disturbances in this region tend to affect these reflections by distorting or blocking them. As it will at once be seen, this is of great importance since d-f equipment, which indicates only the direction from which the incoming signal is being received, will translate into bearings both accurate signals and those that are reflected inaccurately from the ionospheric regions.

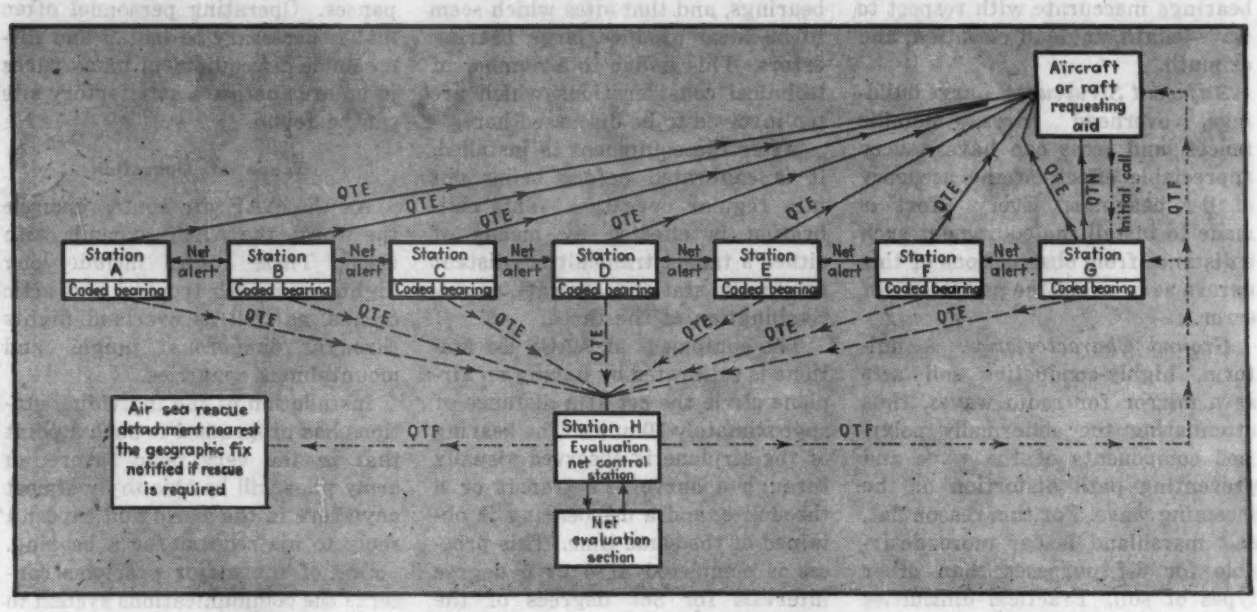
Ionospheric sounding stations located strategically throughout the world will aid in solving this problem by providing forecasts of ionospheric conditions to be expected in various areas and thus permit a more accurate interpretation of bearings affected by these conditions.

Still another major problem was presented with regard to the proper frequencies for d-f operation. The distance between the end of the ground wave and the beginning of the reflected sky wave is called the skip zone. Within this skip zone, communications are said to be impossible, but sporadic E conditions, scattered reflections or ionospheric storms often permit communication in part or all of the zone. Bearings obtained from transmissions within this space, however, are faulty and require correction by means of skip distance charts predetermined for each frequency during each of the six four-hour periods of the day.

Most reflections are controlled by the F_2 layer. This is the layer nearer the sun and for that reason is ionized to a greater degree. Sometimes during daylight hours, however, the E layer (the one nearer the earth) controls these reflections. In plotting frequency-skip curves, the maximum usable frequencies and the optimum working frequencies are first found for each ionized layer. The optimum working frequenceis for each four-hour period are then compared. The layers possessing the larger number of optimum working frequencies are then selected as the controlling layers for the various four-hour periods.

Skip-distance charts are being prepared to enable d-f evaluators of each net plotting station to ascertain the frequency characteristics of the satellite stations whose bearings it receives for evaluation.

As previously stated, the greatest benefit to be derived from direction finding is the position fixing of air-



Typical action sequence of a d-f net follows the notations on this chart. Aircraft at upper right makes initial call for d-f fix, and station G alerts all other stations in the net on point-to-point frequencies or land lines. Next, the called station (G) requests the aircraft to transmit call signs and dashes (QTN) by which all net stations obtain bearings (QTE) and report them to the evaluation net control station (H) where geographical fix is plotted. Finally, the fix is reported (QTF) directly to the aircraft if contact can be established, or otherwise to the originating station. If the plane has crashed or if the transmitter is on a life raft, the fix is reported directly to the air-sea rescue detachment nearest the fix (QTF)

craft in flight. In order to use its equipment to the fullest in the accomplishment of this, the AACS first assigns to the various air routes, areas of 1000 to 1500 miles in diameter. It then establishes within each area a net consisting usually of five or six strategically-located individual reporting stations and a central plotting station.

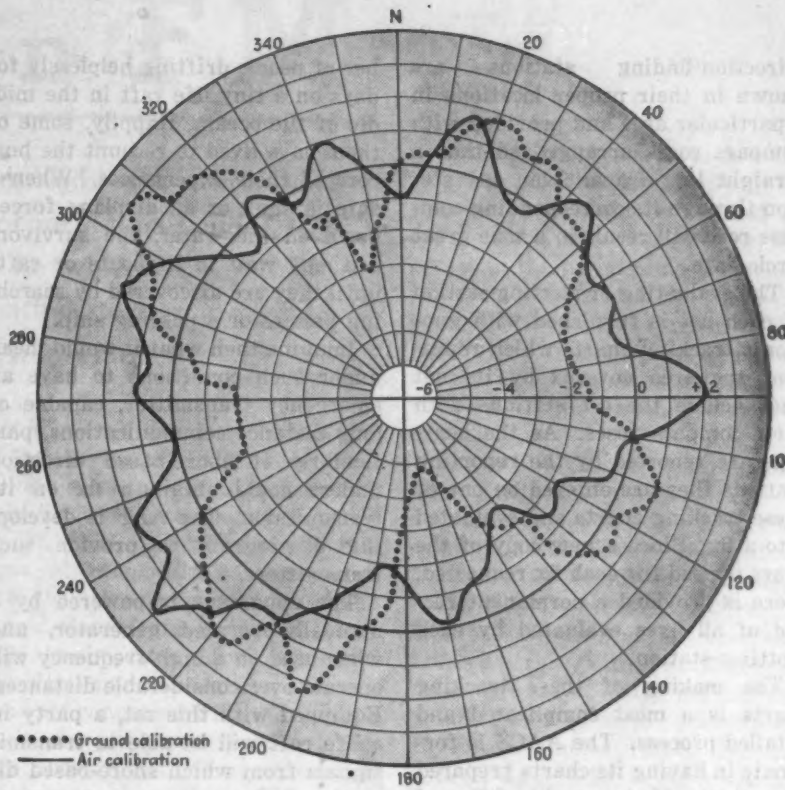
The reporting stations will be from 100 to 600 miles apart, depending upon the size of the area. In many cases, of course, it is impossible to install these individual stations at ideal distances, either because locations cannot be found (as in mid-ocean) or because point-to-point communications do not exist or cannot be used.

Operation of Nets

The most desirable arrangement for net stations in an operational area 1000 miles in diameter consists of a reporting d-f station installed on each corner of a square measuring 600 miles on each side. The evaluation station with its adjacent d-f reporting station (the fifth in the net) should be located at the intersection of the diagonals between the corners. Such an arrangement is seldom if ever possible in actual practice, and over long ocean routes and in foreign countries the right-angle bearings so important to plotting a fix are sometimes unobtainable.

A geographical fix, to be accurate, must have a series of intersecting base lines (individual bearings) from angles as widely separated as possible. If each of them is accurate, only four or five bearings are needed to provide an excellent fix. A larger number of bearings would prove cumbersome and retard the speed of net operation. On the other hand, if the direction finders furnishing these four or five bearings are not properly located, the resultant fix will suffer in accuracy.

For example, let us assume that a net of six stations has been placed in operation and that these stations are spaced from 200 to 400 miles apart in a fairly straight line. A very satisfactory fix could be given to an aircraft located approximately 300 miles out on a line perpendicular to the axis line drawn between the stations—if a majority of the stations obtained accurate bearings.



Ground and air calibration procedures produce two sets of figures which are plotted on circular or linear forms to show error in degrees around station. A third curve is later added to represent computed average error

On the other hand, if the aircraft were 800 miles from the axis line, a poor fix would result unless other nets were employed to provide the necessary right-angle base lines.

In this assumed net an airplane proceeding along the axis line joining these stations would be in such a position that it would be almost impossible for the stations to secure a good fix, again because of absence of right-angle base lines.

It is clear, then, that care must be taken to locate the various installations so that they can provide multilateral coverage. To obtain this coverage it has been necessary to set up installations at points located well off the established air routes. This provides sufficient depth to offset the detrimental factor of skip distance and provide right-angle base lines in a greater number of cases.

It is possible, of course, that more than one net may be operating along the same air route. Under these conditions it will sometimes happen that an aircraft requesting a fix is so located that its position cannot be accurately determined unless bearings are obtained from two or more nets. The procedure governing operation of nets has therefore been developed to include regulations for inter-net coordination.

It thus becomes possible to obtain individual bearings necessary for a fix from all d-f stations receiving the transmitted signal and to report such bearings to the plotting station concerned. Inter-net operation does, it is true, involve a greater time loss, but this delay is justified by the importance of satisfactory operating coverage.

Tracking Charts for Plotting Fixes

The success of a d-f net system depends in large measures on the type of chart employed in plotting the individual bearings. As AACS operations were planned to cover larger distances, the gnomonic projection type chart was selected for this purpose.

A gnomonic chart is a projection of a given area of the surface of the world as it would appear if viewed from the center of the earth.

Direction-finding stations are shown in their proper locations in a particular area and provided with compass roses arranged so that a straight line drawn from any station through its corresponding compass rose will result in a true great circle path.

The evaluating or plotting station of each net is furnished with gnomonic tracking charts which represent the area covered by its net and include the d-f stations with their compass roses. As the bearings are reported by the reporting stations they are entered on one of these tracking charts and evaluated into a fix. Since a new copy of the chart is used for each fix requested, there is provided a permanent record of all fixes evaluated by each plotting station.

The making of these tracking charts is a most complicated and detailed process. The AACS is fortunate in having its charts prepared by both the Hydrographic Office of the Navy Department, and the Aeronautical Chart Service of the Army Air Forces, to which it sends data as new charts are required.

Things to Come

Since the beginning of the war, stories have been told in great number of people drifting helplessly for days on a tiny life raft in the middle of the ocean. Happily, some of them have lived to recount the horrors of their experiences. When a ship is sunk or an airplane forced down on the water, the survivors can only wait in lifeboats or rafts until they are discovered by searching parties or a passing ship.

Imagine then what it would mean under such conditions to have an emergency transmitter, capable of long distance communications, particularly if shore-based direction finders could obtain a fix on its transmission. The AAF is developing a program to provide such transmitters.

The apparatus is powered by a manually-operated generator, and when used on a high frequency will operate over considerable distances. Equipped with this set, a party in a life raft will be able to transmit signals from which shore-based direction finders can compute a geographical fix—to be sent immediately to the nearest sea rescue organization.

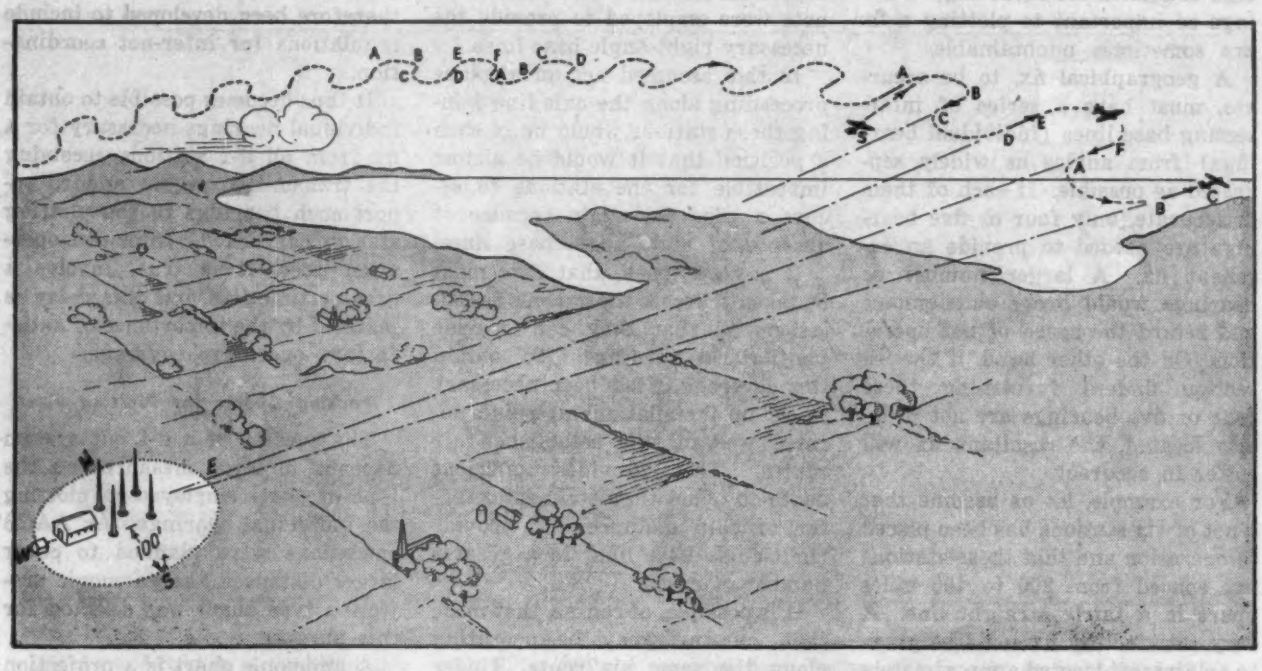
The same method is employed to secure bearings and determine a geographical fix on a life raft as on an aircraft in flight, and the large-scale production of the proposed emergency transmitters will unquestionably prove of tremendous assistance to the men who must make the long, dangerous flights that are inevitable in this war.

Conclusion

The many and complex problems inherent to the placing in effect of such a huge program are too detailed to be treated at any length in this discussion. By the very nature of its operations, which must be accurate in the extreme, radio direction-finding suffers from conditions which do not prove deleterious to the efficiency of ordinary radio communications.

Some of these conditions can in certain instances be anticipated and thus corrected or minimized. Others must remain factors constantly limiting the consistent accuracy and efficiency of the equipment.

Fully conscious of these limitations and the difficulties it will have to face, the AACS continues to expand its facilities. The value of direction-finding in emergencies, in aiding disabled or lost aircraft, more than compensates for every expenditure of time, money, and energy incidental to the installation and operation of the equipment.



Method of air-calibrating a d-f station involves a theodolite at point *S* and an aircraft flying at 5000-ft. altitude 10 miles from the d-f station. Sequence, which is repeated throughout, is as follows: From *A* to *B*, aircraft transmits a series of single dots while approaching course. From *B* to *C*, *D* to *E*, and *F* to *A*, while on course, ten-second dashes are sent. From *C* to *D* are transmitted a series of two dots and from *E* to *F*, a series of three dots

RTPB on FM

Panel 5 reaffirms existing standards of transmission, and proposes allocation of a continuous band of 80 to 100 channels, each 200 kc wide, from 40 Mc upward. "Bursts" and multipath distortion are found to be of minor importance

THE V-H-F Broadcasting Panel of the Radio Technical Planning Board has issued its report on post-war plans for frequency modulation. The Panel recommendations make no break with past practice, since all the basic standards of transmission are reaffirmed, and one additional standard proposed. In the matter of proposed frequency assignments, a conflict arises with the previous recommendations of the RTPB Television Panel, in the region of 50 to 60 Mc. Here the proposals of the two groups overlap somewhat, with the amateurs sandwiched in between.

Recommendations

The specific recommendations of the FM Panel are as follows: (1) Frequency modulation is the system best suited for v-h-f broadcasting. (2) The f-m broadcast band should extend upward from approximately 40 Mc. (3) The width of each f-m channel should be 200 kc (this implies 75 kc maximum frequency swing and 15,000 cps maximum audio frequency). (4) From 80 to 100 channels are necessary for a national allocation, allowing for educational stations as well as commercial broadcasters. (5) The direction of polarization should be horizontal.

Sudden increases of signal strength lasting from a fraction of a second to several seconds have been noticed recently on distant stations operating in the 40 to 50-Mc band, due possibly to reflections from ionized patches caused by the passage of meteors. It was argued that the existence of such bursts of interference, as well as the probable increase of long-distance propagation at times of sunspot maximum (every eleven years) would cause difficulty to f-m service if the present region between 40 to 50 Mc were preserved for future use. The issue was finally referred to Dr. J. H. Dellinger of the Bureau of Standards, who reported that the existence of short bursts of long-distance interference is probably closely connected with sporadic E reflections in the ionosphere, and thus not connected with the sunspot cycle. In any event, he stated, the effects were not prevalent enough to impair the value of the frequencies seriously. He stated further that no frequency in the spectrum can be said to be free of transmission vagaries.

The Panel discussed at some length the multipath distortion effects reported by DuMont, which arise when a wave reflected from a building or other structure arrives at a receiver in strength comparable to that of the directly propagated wave, causing wave cancellation and a-f distortion. The panel came to the same conclusion reached earlier by the Television Panel, namely that such effects could be found, but that they were not sufficiently prevalent to warrant any change in the method of modulation or in the frequency swing.

Channel Width

A reduction of the channel width from 200 kc to 100 kc was discussed at length. The advantages claimed are reduction in the amount of ether space for the required 80 to 100 channels, consequent improvement in image rejection, reduction in multipath interference effects, and higher gain per stage in i-f amplifiers without loss in interchannel selectivity. The disadvantages are a loss of 6 db in signal-to-noise ratio throughout the service area, a reduction of the service area within which 60-db maximum signal-to-noise ratio could be realized at the receiver, and a two-to-one decrease in the permissible frequency tolerance of the local oscillator in push-button operated receivers. The possibility of multiplex operation on the f-m channel would also be removed if the channel were reduced.

It was brought out that the optimum frequency swing for 60-db maximum signal-to-noise ratio (assuming a maximum modulating frequency of 15,000 kc) is about 125 kc, a figure considerably greater than the 75-kc swing now used and proposed for future standardization. The 125-kc swing permits the greatest area to be served with 60 db signal-to-noise ratio. Smaller swings, e.g., 75 kc, serve a smaller area with this signal-to-noise ratio, but a larger area with somewhat lower signal-to-noise ratio. The choice is thus a compromise between space used in the spectrum and area covered with the desired low level of noise interference.

The proposed number of channels for a national allocation, 80 to 100 channels, is based on a service comparable in scope to the present system of standard broadcasting, in which 105 channels are available. The greater interference radius of the standard broadcasting frequencies makes it impossible to provide noise-free service from all stations, particularly at night. Therefore a smaller number of f-m channels can be expected to give an equal or greater choice of program with virtually no interference at any time. Of the channels proposed, about 15 are expected to be reserved for educational stations.

The proposal to standardize on horizontal polarization is a distinct step forward, and should ultimately correct the present situation in New York, where eight f-m stations are about equally divided between vertical and horizontal polarization, making it difficult if not impossible to obtain optimum reception from all stations with a single receiving antenna.

FREQUENCY-SHIFT Radiotelegraph

Frequency-shift transmission of telegraph, teletype, facsimile and radio-photograph signals provides the advantages of f-m over a-m without the usual increase of bandwidth. A special circuit eliminates the effect of mean-frequency drift. A limiter that is free from loading and transients is described

COMMERCIAL radio communication by Morse Code has been standard since the advent of radio. The dot-dash system has never been entirely superseded by voice. Though code has its drawbacks and is subject to error in transmission, and requires highly schooled personnel, it is still the basic means of handling high-speed commercial and press traffic.

Anyone who has operated on noisy long-distance circuits realizes how much more accurate it is to receive by ear than by automatic slip recorders. When the signal is strong and no noise is present, tremendous speeds may be attained by using automatic equipment, but if the noise level rises, automatic equipment fails, speeds decrease and manual operation must take over; traffic piles up.

Developments over the past five years have produced a new system of automatic code transmission and reception which performs electronically what the human ear or brain does with a signal in the presence of noise. This system reaches in and picks out the signal despite the noise.

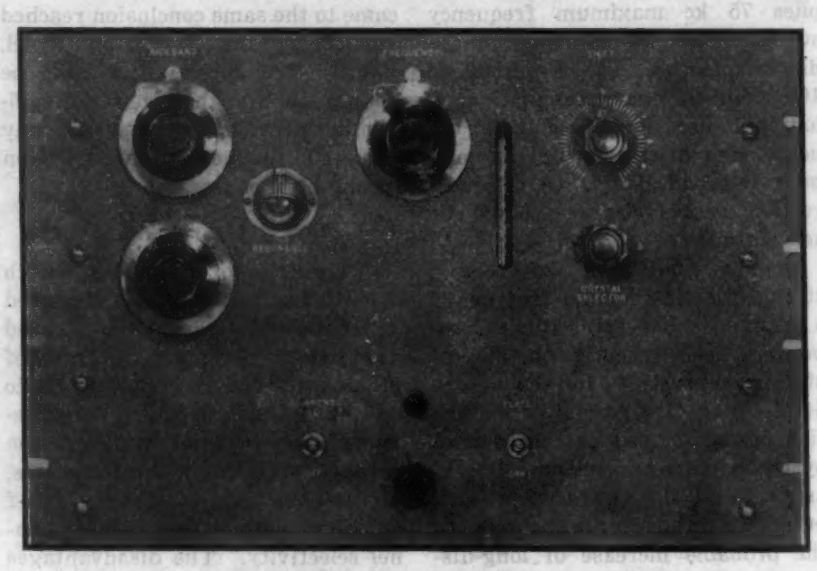
Noise Suppression Without Increased Bandwidth

Everyone is familiar with the improvements in signal-to-noise level in broadcasting that frequency modulation provides over amplitude modulation. Frequency modulation presents only one disadvantage, the required bandwidth is over ten times that required for a-m systems. Developments in the transmission of telegraph signals are now being made which are analogous to f-m broadcasting. Instead of keying a carrier on and off to designate the mark and space of telegraph signals, the transmitter maintains radiation at full power, but the carrier is shifted back and forth between two distinct frequencies to designate mark and space. The same beneficial reduction in signal-to-noise ratio is derived in transmitting telegraphy in this manner as is derived from f-m broadcasting. However, in regard to bandwidth the analogy fails. The bandwidth required by frequency-shift transmission is no greater than that required by the carrier make and break system.

This new type of transmission is not only applicable to the transmission of telegraph signals, but can also be used for transmission of teletype mark and space signals, or for facsimile where one radiated frequency corresponds to black and the other to white. This system can be extended further to the transmission of radio photographs. In this application the half tones are represented by frequencies intermediate between the extreme black and white frequencies.

Early Use of Frequency-Shift

Frequency-shift transmission was used long before it was recognized as such. In the days of arc transmitters it was impossible to interrupt the arc in accordance with telegraph signals, so instead the frequency of the transmitter was shifted during the space. Here



Front panel of frequency-shift transmitter terminal equipment used by Press Wireless, Inc.

By ROBERT M. SPRAGUE
Director of Research
Press Wireless, Inc.
Little Neck, New York

and Teletype System

was true frequency-shift transmission, but at the receiver no use was made of the all-important space wave. By the late 1930's the advantages which seemed inherent in this system were being developed in the laboratory.

When the Byrd South-Pole expedition of 1939–1940 was about to leave, equipment from Press Wireless laboratories was rushed into readiness and, with Times Wide World wirephoto equipment, was sent along with the expedition. Pictures published in daily newspapers during the expedition gave ample proof of the effectiveness of this type of transmission. Pictures coming over 8000 miles from a small 500-watt transmitter were received with the clarity of standard wirephoto pictures. Further developments were made over circuits from Berlin, Moscow, London and Chungking. Such transmissions are now commonplace.

Frequency-shift transmission for radio telegraph was slower in coming, but when it was proved that a 20-db increase in signal-to-noise ratio was available, the system was applied to this service. Now many commercial circuits are operating both telegraph and teletype by means of carrier shift.

Frequency-Shift Transmitter

Several types of carrier-shift equipment are being used. The transmitting equipment developed by Press Wireless, Inc. takes energy from a crystal oscillator and beats it against an extremely stable self-excited 200-kc oscillator. The frequency of the self-excited oscillator is shifted by the signal which is to be transmitted, being increased in frequency on mark and decreased on space.

The incoming signal, usually in the form of a square wave, is filtered to eliminate frequencies higher than the third harmonic of the highest keying frequency required. The filter must be designed so that the fundamental to third harmonic phase relation is not changed. Such filtering introduces only 1.35 percent characteristic distortion, and aids in reducing the bandwidth which must be transmitted.

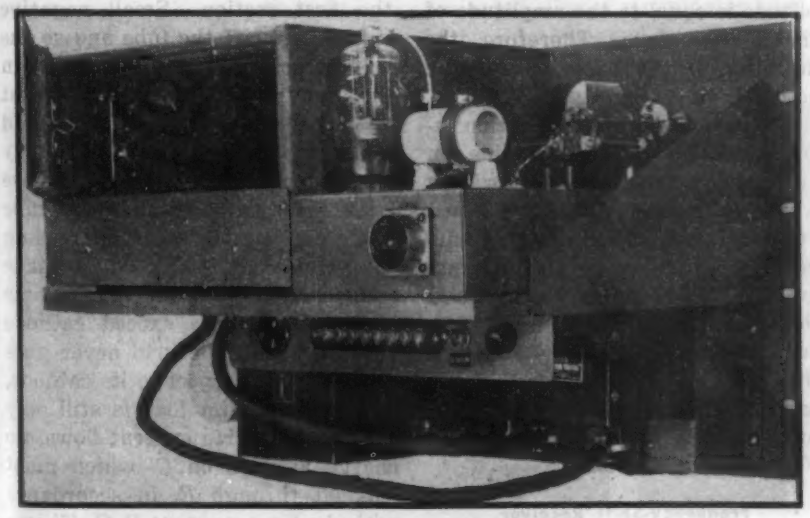
From the output of the mixer stage of the crystal oscillator and the self-excited oscillator, the upper side band is selected and applied to doublers and power amplifier stages of the transmitter, and radiated on frequencies varying symmetrically about the assigned frequency.

A frequency shift of 850 cycles has been adopted as standard because it gives the best compromise between signal-to-noise level and bandwidth. However, this shift is varied between 400 cycles and 1200 cycles for special services. For example, high-speed facsimile and photograph services use a 1200-cycle shift.

Transmission Bandwidth

Consider the bandwidth for the case of teletype, the signal for which is a 23-cycle fundamental and a third harmonic of one-third the fundamental amplitude. If the carrier were keyed make and break by this signal, the ideal bandwidth would be twice the third harmonic frequency, or 138 cycles. Such a narrow band is never attained because the amplifier stages of the transmitter tend to square the keying signal. The best possible transmitter adjustment will require a bandwidth of approximately 1200 cycles. Only side bands greater than 40 db below the unmodulated carrier level are considered in this value. If, on the other hand, the carrier is shifted 850 cycles by the teletype signal, the emitted bandwidth is 1100 cycles. Were the carrier shift reduced to 250 cycles with the same signal, the emitted bandwidth would be only 480 cycles. Thus frequency shift can result in a much lower bandwidth than carrier make-break.

The calculation of frequency-shift bandwidth is comparatively simple. Assume that the carrier is shifting from mark to space frequencies sinusoidally, for teletype at a frequency of 23 cps. This is equivalent to frequency modulation



Rear view of frequency-shift transmitter unit showing crystal oven and shifting oscillator

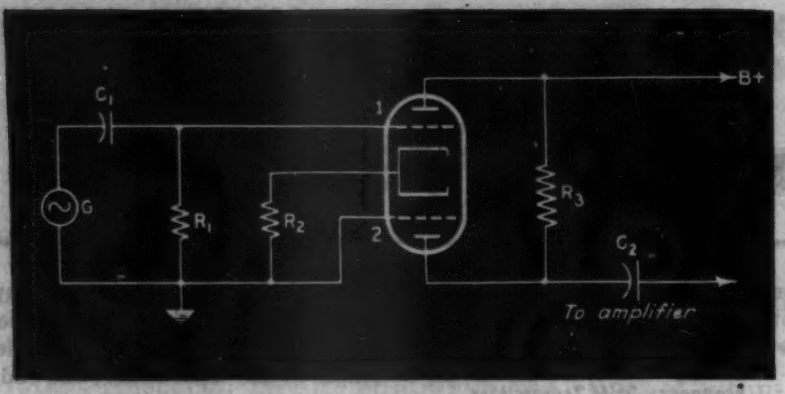


FIG. 1—Transient-free limiter in which the first section of the double triode limits the negative peaks, and the second section, cathode-coupled to the first, limits the positive peaks

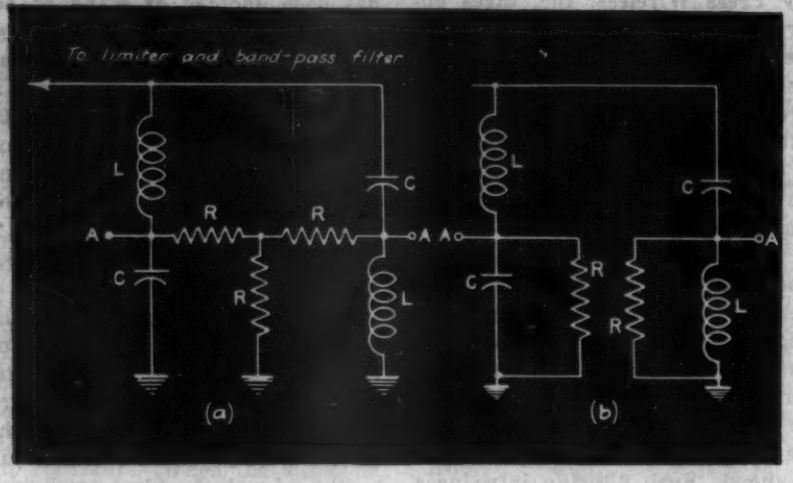


FIG. 2—Two forms of discriminator. The discriminator for frequency-shift reception must be flat over a band far wider than the deviation limits, so as to avoid amplitude modulation in the output produced by the noise in the input

of a carrier whose frequency lies midway between the mark and space frequencies, by a 23 cps signal. The modulation index B is the deviation from the carrier frequency divided by the modulation frequency. For a total shift of 460 cycles, $B = 230/23 = 10$. Under this condition there are 14 pairs of side frequencies greater than 40 db below the unmodulated carrier level. Therefore, the bandwidth is $23 \times 28 = 645$ cycles.

Now consider the third harmonic along with the fundamental. The keying wave is a signal of varying frequency and amplitude. At any instant the transmission band is determined by the instantaneous frequency and amplitude of the keying wave. Therefore, the transmission band varies between maximum and minimum values. The maximum instantaneous keying frequency, with its corresponding amplitude, determines the transmission bandwidth. This maximum instantaneous frequency in this case is 1.5 times the fundamental frequency, and its amplitude is equal to the amplitude of the keying wave. Therefore, the deviation is the same as for the actual keying signal.

The corresponding modulation index is $B' = \Delta F/1.5\,f$. This value can be used to calculate all bandwidths where the keying wave is composed of a fundamental and its third harmonic. Returning to the original example, $B' = (B/1.5) = 6.67$, and the maximum instantaneous frequency is $f' = 1.5\,f = 34.5$. For a B of 6.67 there are ten significant pairs of side frequencies, and therefore the maximum bandwidth is $20 \times 34.5 = 690$ cycles.

Frequency-Shift Receiver

The receiving systems of various commercial companies using frequency-shift transmission are similar in principle, but use different types of equipment.

Press Wireless, Inc. uses an a-m communications receiver which receives the radio signal and delivers an audio beat note to a band-pass filter. The beat note shifts in frequency about a mean frequency of 2550 cycles in accordance with the transmitter frequency variations. The band-pass of the filter must be wide enough to pass not only the two frequencies between which the audio beat-note shifts, but also all sidebands produced by the frequency modulation which are one-tenth or more of the carrier level. It must also be wide enough to tolerate possible transmitter or receiver drift. Noise signals outside the band are not completely eliminated but, due to filter transients, are reintroduced as signals of much lower amplitude and at frequencies within the filter pass-band.

Transient-Free Limiter

From the filter, the signal goes to a power limiter. The requirements of this limiter are much more stringent than those of the rf limiter used in f-m broadcasting because the carrier and intelligence frequencies are comparable. Thus transients must be extremely short compared to both carrier and intelligence frequencies.

Such a limiter is shown schematically in Fig. 1. The tube is a dual high-mu triode. Consider the effect of a high-amplitude signal applied through capacitor C_1 to the grid of the first section. Small negative voltages cut off the tube and so the voltage across R_2 due to current in the first triode is zero during most of the negative half cycle. The load resistance of the generator is only R_1. As the grid swings positive with respect to ground, the tube space current increases, increasing the voltage across R_2. R_2 is made sufficiently large so that at no time does grid voltage exceed cathode voltage. Thus the grid never goes positive with respect to its cathode, and the generator load is still only R_1. Since no grid current flows, no charge appears on C_1 which must leak off through R_1 in accordance with the time constant R_1C_1. Therefore the circuit is instantaneous in its action and no transients result.

Also, the load presented to the generator remains constant.

As the voltage across R_k increases because of positive swing of the first grid, the second triode is cut off. This second triode is essentially a cathode drive stage excited by the first triode acting as a cathode follower. The gain of the second triode is low because its plate resistor R_k is small. It cuts off at about the same positive swing of the first triode grid as does the first triode for negative swings of its own grid. Therefore the action of the limiter is symmetrical about the zero axis, and is both transientless and instantaneous for any abrupt level or frequency change. The limiter gives about 30 db of limiting. Two limiter stages separated by a class A amplifier supply the needed 60 db of limiting.

Discriminator Requirements

Once the signal has been limited, it is fed into a sloping discriminator circuit prior to detection. The requirement of the discriminator is that it be linear over a frequency range far in excess of the deviation band. It need not be the back-to-back variety which is symmetrical about zero, zero voltage corresponding to the mean frequency. Following is the argument for these statements.

In f-m receivers, the tuned circuit following the limiter is usually part of the discriminator circuit. The circuit is linear only over the deviation band. Beyond this band, the response of the tuned circuit falls rapidly to zero. Therefore, any signal outside the deviation band is not received by the detector. With an input level variation of 60 db the limiter delivers a constant output. Whether the input consists of one or a thousand frequencies, the output energy is constant and is made up of one or a thousand frequencies. With one frequency fed into the limiter, the output is of the same frequency, plus its odd harmonics due to the wave squaring of the limiter. But when noise is present, side bands of the original signal become evident, and these side bands extend far beyond the band-pass filter, which accepts noise at the input of the limiter. The greater the intensity of noise in relation to the desired signal, the greater the amplitude of these side bands, and the greater their coverage of the spectrum beyond the deviation band.

In f-m receivers the tuned circuit following the limiter eliminates these frequencies which lie outside the deviation band. Since the energy output of the limiter is constant, the output of the tuned circuit following the limiter must change in amplitude as noise is impressed with the signal on the limiter input. This amplitude change will be as evident after detection as will be the desired change due to frequency modulation. Therefore, a back-to-back discriminator is required.

Such a discriminator operates in push-pull for frequency changes, but in push-push for noise-caused amplitude changes. These latter, therefore, tend to balance and be eliminated. The discriminator need not be linear beyond the deviation band, as no side bands are present, having been filtered out by the tuned circuit following the discriminator. Notice that the back-to-back discriminator is superior to a single-ended non-symmetrical discriminator only in suppressing the amplitude-modulation effects of noise, and not phase or frequency-modulation effects. These latter effects are additive in each half of the back-to-back discriminator and no noise reduction results.

Single-Ended Discriminator Preferred

In many commercial types of converters, the limiter is followed by a single-ended slope circuit. No attempt is made to eliminate noise sidebands outside the deviation spectrum. When such a discriminator is used, it must be of the extended range type, i.e., it must be linear far beyond the deviation band so as not to discriminate against noise components. Otherwise, amplitude modulation resulting in noise will result. Under these conditions, no advantage whatsoever accrues from the use of a back-to-back discriminator. After the discriminator and detector, the signal should be fed through a low-pass filter to eliminate noise caused by phase modulation of the signal at frequencies higher than the desired intelligence frequency. For teletype this filter passes the third harmonic, which may be 70 to 100 cps; for high speed Morse, 250 cps, and for photograph and facsimile, 600 cps.

An extended-range, single-ended discriminator eliminates all amplitude modulation due to noise, but

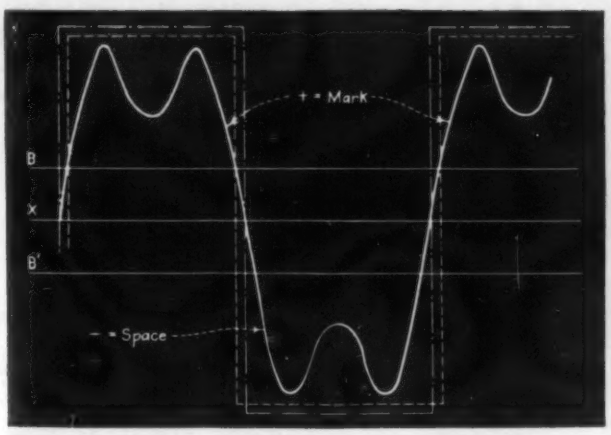


FIG. 3—The pulse consists of the fundamental and third harmonic. Pulses should vary about the central axis

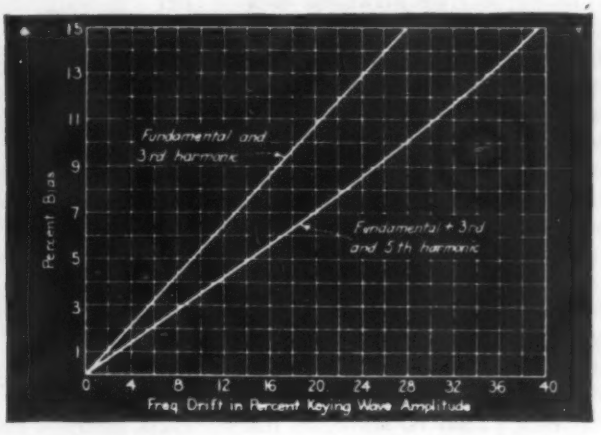


FIG. 4—Bias introduced by transmitter or receiver frequency-drift for two types of keying waves

accepts a wider band of noise to phase-modulate the signal, whereas the pre-filtered back-to-back discriminator only partially eliminates amplitude modulation due to noise, but limits the band of noise to phasemodulate the signal. Experiments have shown a small but definite advantage in the latter type; therefore its use is recommended in all types of terminal equipment for teletype, photo and facsimile.

Such a discriminator is shown in Fig. 2(a). The differential voltages to be detected are taken off at points *A*. In both Fig. 2(a) and 2(b), the input impedance of the discriminator is a constant over the band equal to *R*. *L* and *C* are given by

$$LC = \frac{1}{\omega^2} \qquad \frac{L}{C} = 2R^2$$

where ω is 2π times the cross-over frequency. The configuration of Fig. 2(a), although it does not give linear response over as wide a frequency range as does that of Fig. 2(b), delivers a higher output voltage and is perfectly symmetrical.

Frequency-Drift Compensation

The output of the detector and noise filter is the recreated pulse that originally keyed (frequency-shifted) the transmitter. If the mean frequency of the signal being fed to the converter equals the cross-over frequency of the discriminator, the pulse will alternate symmetrically about a zero axis. The solid curve of Fig. 3 represents such a keying signal, composed of fundamental and third harmonic, oscillating about the *X* axis. A local oscillator may be arranged to key on and off around this zero axis. However, if the frequency of the receiver or transmitter drifts so that the mean frequency no longer corresponds to the discriminator cross-over point, the local oscillator will no longer key on and off symmetrically about the axis, but about some other axis *B*.

When keying takes place about the *X* axis, a square wave shown by the dot-dash line results from the fundamental-third harmonic keying wave. This square wave is unbiased. That is, for equal mark and space of the transmitted wave, the square-wave mark and space are equal. However, when keying about the *B* axis, it can be seen that mark and space are no longer equal and a bias (expressed in percent as 100 times mark-length minus space-length, divided by mark-length plus space-length) results. For an acceptable minimum number of errors, teletype signals can contain no more than 5 percent bias; therefore, any frequency drift will result in more errors.

Figure 4 shows the bias introduced by transmitter or receiver drift expressed as a percent of the frequency shift for the fundamental-third harmonic keying wave and for a fundamental plus third and fifth harmonic keying wave.

To eliminate bias due to frequency shift, the circuit shown in Fig. 5 is used. Here the keying

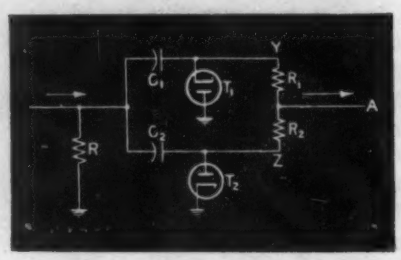


FIG. 5—Balancing circuit used to center the received pulse about the zero potential axis in the event that frequency drift throws it off

wave is developed across *R*, which is capacitively coupled through C_1 and C_2 to rectifiers T_1 and T_2 connected as shown. The load circuit consists of equal resistors R_1 and R_2, with the keying signal taken off at their junction, point *A*. As the signal across *R* increases positively, capacitor C_2 charges through rectifier T_2 thus holding point *Z* at zero potential. At the same time this positive potential is passed through capacitor C_1 to point *Y*. Rectifier T_1 is non-conducting for this polarity. As the voltage across *R* falls to zero and swings to its negative value, the charge on C_2 is applied to point *Z* and the full peak-to-peak voltage appears at *Z*. The voltage at point *Y* falls to zero and capacitor C_1 is charged through rectifier T_1 to the negative value of the voltage across *R*.

On the next positive swing of the cycle, the full peak-to-peak voltage is applied to point *Y*. Thus, point *Y* is varying between a positive value equal to the peak-to-peak voltage across *R* and zero, while the voltage at *Z* is varying between zero and this same peak-to-peak value, but in a negative direction. Therefore, the voltage at point *A* is always varied symmetrically, plus and minus, around zero. Any direct component in the voltage across *R* is not transmitted to point *A*.

The conditions to be satisfied in this circuit are that the time-constant RC_1 or RC_2 be small in comparison with the length of the keying pulses, and that the time constant $C_1(R_1 + R_2)$ is large in comparison with the time interval between pulses. With this circuit, the system is always operating essentially about the *X* axis of Fig. 3.

Gas Tubes Block Noise

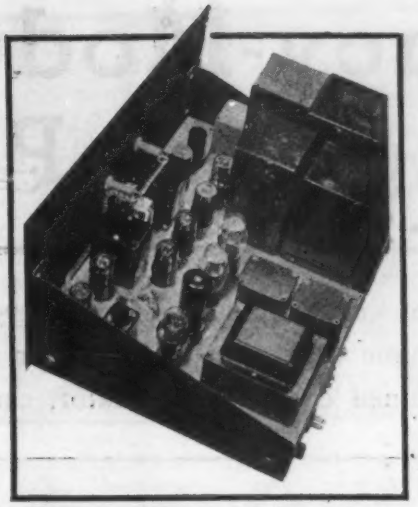
The keying pulse, as shown in Fig. 3, is now set to key on and off around axis *X*. However, if the crest of the signal has been reached and is holding the local oscillator in its mark position, a noise crash which causes the voltage to drop below the *X* axis will shift the local oscillator, causing it to record a false space. Much greater signal-to-noise ratio can be obtained by using gas control tubes, which strike on and off only after a critical voltage is reached. Under such conditions, these tubes can be adjusted to key the mark signal on at, say, level *B* of Fig. 3, and off at level *B'*. Thus, when the keying voltage is on its positive swing a noise crash must force the keying wave to pass the *X* axis and deviate all the way to the *B'* axis before a false space will be recorded. Similarly, when the keying wave is on its negative half-cycle a noise crash must force the voltage beyond the *B* axis before a false mark will be recorded. The use of gas tubes does not introduce bias, but merely displaces the keying wave slightly, and gives a much greater signal-to-noise ratio.

Combining Circuit for Diversity Reception

Still more faithful reproduction is had by using diversity reception. However, the receiver output in a two-receiver diversity system cannot be combined directly, as fading and phase shift would cause the resultant signal to fluctuate violently

in level. Furthermore, a signal fading in relation to noise on one circuit would, because of the limited action, result in a high noise output of the limiter. Instead, the signal from each receiver is fed through two similar channels, each consisting of an input filter, limiter, discriminator, detector and noise filter. Combination of the signals takes place at this point, where the frequency is low and time delay effects are at a minimum.

Referring to Fig. 6, the keying wave appears across R_1 for one channel and across R_1 for the second channel. These keying waves are varying symmetrically around the zero axis. The voltage across R_1 and R_1' are combined through four rectifiers poled as shown in Fig. 6. R_2 and R_2' are the load resistors for these rectifiers. The centers of the rectifier circuit are also connected by resistors R_3 and R_4, and the combined voltage taken out at their junction point A. With either a positive or negative voltage simultaneously on R_1 and R_1', half this voltage appears at point A. However, if due to diversity action the voltage across R_1' drops to zero, while the voltage across R_1 remains constant, the voltage at point A will also remain constant, thereby giving full diversity effect. Even though the voltage across R_1' should go negative when a positive voltage is desired, the voltage at point A will not drop to less than zero. Using the gas tube action outlined above, no false signal will be recorded as long as one circuit maintains its full voltage. Use of this type of diversity combination results in 10 to 20-db increase in signal-to-noise ratio. In the circuit shown, R_3 must be large compared to R_1, and R_4 and R_4 large compared to R_3.



Frequency-shift converter for receivers

Cause of Lower Signal-to-Noise Ratio

The signal-to-noise improvement using frequency-shift transmission occurs for the same reasons that such improvement is obtained in f-m broadcasting. The following remarks may serve to clarify the reasons why there is such improvement. With constant-frequency carrier make-break transmission, noise in the presence of the mark signal tends to amplitude-modulate the signal in direct relation to the signal-to-noise ratio. Noise in the presence of no signal will cause interference depending only on the amplitude of the noise. Where a large mark-to-space signal-ratio is required for automatic recording, a small amount of noise will, therefore, introduce false mark and space signals.

In frequency-shift transmission, however, the signal is first fed through a limiter. This limiter eliminates all amplitude modulation caused by noise. There is always a signal feeding the limiter whether it be of mark or space frequency, and thus noise effects will act the same on mark as on space. If noise is fed into a limiter simultaneously with the signal, only phase modulation of the signal results. If this noise consists, for the purpose of analysis, of only one frequency, the phase modulation of the signal is given by

$$\frac{r^2 + r\cos\phi}{r^2 + 2r\cos\phi + 1}$$

where r is the noise-to-signal voltage ratio and is less than 1, and ϕ equals $2\pi ft$, f being the difference between the noise and signal frequencies. In the case of noise consisting of many frequency components, only those components whose vector sums are frequencies lying within the band passed by the noise filter following the detector need be considered. All other components are eliminated by this filter.

From the above expression it can be shown that in the case where the vector sum of the noises is as much as half that of the signal there is only one radian of phase modulation. But frequency-shift transmission employs many radians of shift. The modulation index B is often as high as 10 or 20. Therefore, noise, even though it be half that of the desired signal ($B = 1$) will, after detection, be small in comparison to the signal.

As much as 20 db signal-to-noise increase can be expected using frequency-shift transmission. A small, mobile 400-watt frequency-shift transmitter on the beachhead in France is transmitting press traffic to this country at a rate of 500 words a minute, over a million words a month, where in former days a 50-kilowatt transmitter had trouble in maintaining the circuit.

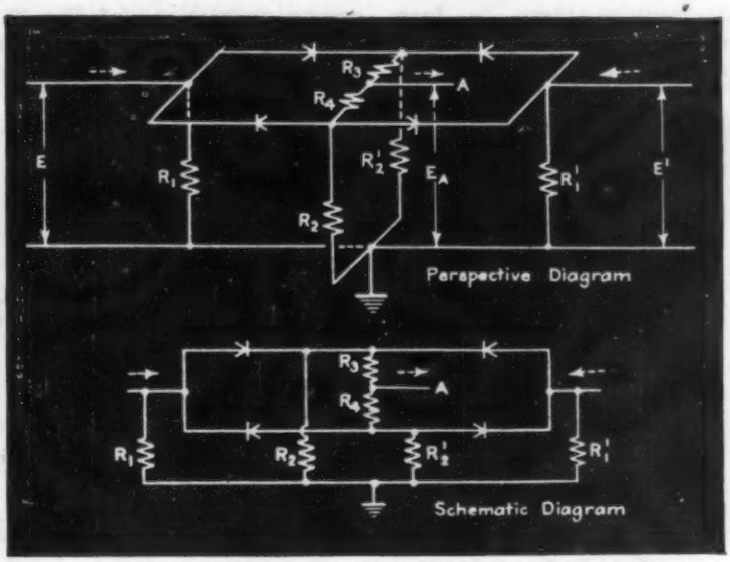


FIG. 6—Coupling circuit used between the outputs of two diversity receivers and the recording apparatus

Frequency-Modulation Phonograph Pickup

Description of a phonograph pickup having a flat frequency characteristic over the audio range, with self-contained volume expansion and less than one ounce of needle weight. Needle varies capacitance in tuned circuit of oscillator, causing frequency modulation

By B. F. MIESSNER
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TO reduce the mass of the moving part of a phonograph pickup, the principle of capacitance translation has been adapted to pickup design. The needle alone is the moving member. Although the variation in capacitance between the vibrating needle and a fixed electrode is small, it is sufficient to frequency-modulate an oscillator operating in the very-high-frequency range. This reduction in mass of the moving part improves the mechanical properties of the phonograph. The frequency-modulation method of translation, being independent of the rate at which the needle vibrates, gives flat frequency response over a wide audio range.

Mechanical Construction

In a simple frequency-modulation pickup the needle constitutes a part of the electrical circuit and therefore should not require replacement more often than absolutely necessary. A semi-permanent needle having a sapphire tip meets the requirements. The upper end of the needle shaft is ground to a point and presses upward into a conical metal socket of slightly larger taper than the shaft point, as shown in Fig. 1. The needle is maintained in position by a soft rubber disk mounted in the bottom of the pickup head and through which the needle passes. A small shoulder on the needle causes the rubber to belly slightly downward so that it exerts an upward force on the needle to hold it in the conical socket. The needle is thus free to move in any horizontal direction. The upper point and socket act as a pivot of microscopic size, with only the slight compliance of the rubber disk restricting the needle motion.

The pickup electrode is mounted to one side of the needle shaft near the lower end, and is roughly parallel to the record groove. Lateral movements of the needle, caused by the record groove, serve to vary the distance between the needle and the electrode.

The only work required of the record groove is to vibrate the minute mass of the needle and overcome the small compliance of the rubber disk, hence needle pressure can be low. This reduces surface noise. Many conventional pickups require three to four ounces of tone arm and pickup head weight on the needle, but this f-m pickup requires only about one-half to one ounce of weight on its needle.

Automatic Volume Expansion

A unique feature of this pickup is its volume expansion. Since the needle is free to move in all directions perpendicular to its axis, there is motion in the direction of the record groove caused by the drag of the record on the needle. This drag is nearly proportional to the deviation of the groove. The groove undulations for stronger sounds are larger than for weaker ones, although not as large as they should be for full dynamic reproduction because of the volume compression used in the recording.

With the pickup electrode at an angle to the groove as illustrated in Fig. 2(a), the increased drag on the needle caused by the larger groove undulations of Fig. 2(b) and 2(c) serves to decrease the average spacing between the

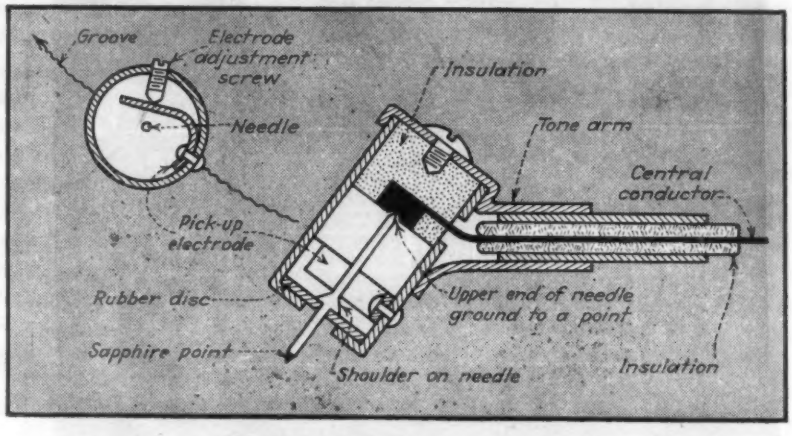

FIG. 1—Head assembly of the f-m phonograph pickup. The arrow indicates the direction of record groove movement

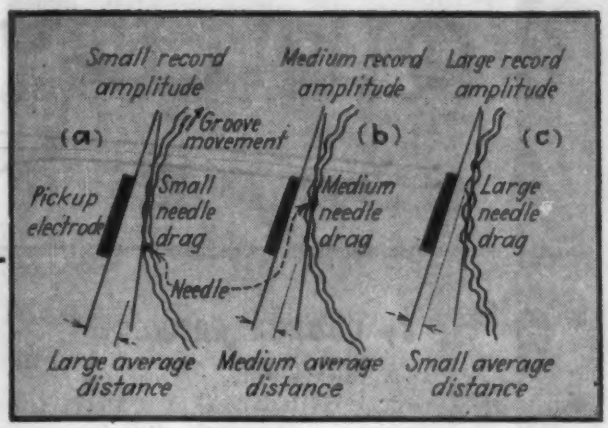

FIG. 2—Volume expansion is obtained by placing the pickup electrode at an angle to the record groove motion. The movement of the needle by groove drag produces volume expansion

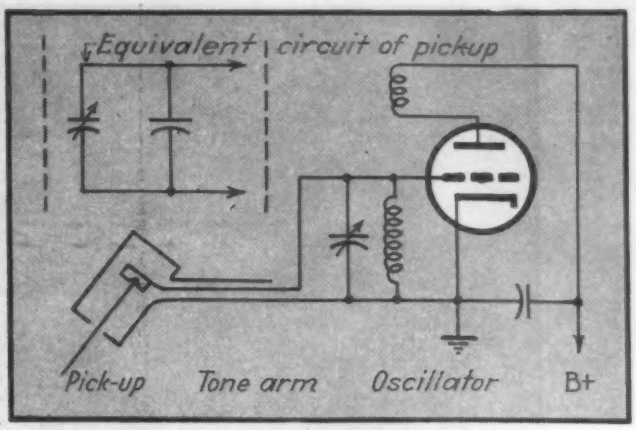

FIG. 3—Schematic diagram of a simple oscillator, showing the connection to the pickup. The equivalent electrical circuit of the pickup is a fixed capacitor paralleled by a variable capacitor

needle and the electrode. Under this condition the variation in needle-electrode capacitance becomes a greater part of the average needle-electrode capacitance, and the translation efficiency is increased. In this manner the recording is volume-expanded to recover the original compression.

The degree of volume expansion can be regulated by adjusting the angle of the electrode surface to the record groove. An angle of thirty degrees gives a realistic degree of expansion. If the electrode surface is parallel to the record groove at the point of needle contact, there will be no expansion.

Surface noise is already much decreased by the low needle pressure on the record groove, and volume expansion gives further reduction. As a result, surface noise is hardly audible with the weakest sounds, and is inaudible with stronger sounds. Amplifier gain control as a means of volume expansion maintains the reproduced signal-to-noise ratio at the recorded ratio, whereas this volume-expansion method of translation-efficiency control reduces the relative noise level as the signal is increased.

Flat Wide-Range Frequency Response

Another contribution to the fidelity of reproduction is given by the flat frequency response characteristic of the pickup itself. For a given needle deflection in the audio range, no matter whether it be at a rate of ten or ten thousand cycles per second, the frequency deviation of the oscillator is the same amount. Thus the frequency characteristic of the system is not influenced by the pickup itself.

The needle is locked at its upper end in the fixed socket, is locked into the record groove at its lower end, and is itself extremely stiff in comparison to the stiffness of the rubber centering disk, hence the needle can have no mechanical resonances in the audible range. This feature eliminates mechanical resonances and the distortions which they introduce, and thus contributes further to reproduction fidelity. Conventional pickups have one or more resonance periods due to freely swinging parts such as a crystal or armature.

Since the needle scratch is very low, no scratch filter is required. Full use can be made of the high-frequency response of the pickup.

Circuit and Operation

An f-m receiver is used for reproduction of the output of the f-m phonograph. To change from station reception to the phonograph, the receiver is tuned to the f-m phonograph oscillator, a simple form of which is shown in Fig. 3. The tube and circuit components can be located in the mounting box containing the gimbals for the tone arm. The tone arm is a tube with a central conductor wrapped with cotton or other electrical insulation. The insulated conductor should be pulled tightly into the tone arm, to maintain constant capacitance between the central conductor and the tone-arm tube. The wrapping effectively damps any tendency of the inner conductor to vibrate. Lower-loss insulation may be used, but it should have mechanical damping properties.

The central conductor connects with the phonograph needle through the conical metal socket. The pickup electrode connects to the tone arm, which is grounded to provide shielding and to minimize stray capacitance effects. The capacitance of the central conductor to the tone arm is in parallel with the pickup capacitance between the needle and the pickup electrode, hence this capacitance should be minimized for highest percent frequency modulation by the needle vibrations. A tube with an inner diameter of $\frac{3}{8}$ inch is satisfactory. Condenser microphone cable with the shield removed serves satisfactorily for the inner conductor.

To decrease variations of the oscillator mean frequency due to movements of the tone arm, and to reduce to a minimum the shunting capacitance of the line through the tone arm, the oscillator can be built into the tone arm or the pickup head.

For a complete f-m receiver with audio amplifying and reproducing systems already available, only the pickup assembly and f-m oscillator of very low power, together with switching arrangements for starting the oscillator, are required. The f-m phonograph oscillator is set for some unused part of the f-m band and tuned in on the receiver as are broadcast stations. The phonograph unit may be separate and remote from the receiver.

QUALITY

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Operator preparing to apply a static quality test to a type 833A transmitting tube

PRESENT-DAY mass production lends itself admirably to quality engineering practices. Although this article is centered on vacuum-tube manufacture, the approach and much of the technique are directly applicable to other phases of industry.

Quality Tests

In order to determine vacuum-tube *quality*, it is necessary to have a criterion of acceptability; in other words, the tube must pass some sort of a test. One method tests a random sample (typical of the day's production) for static characteristics and dynamic performance. All conditions of the test are recorded and readings are meticulously observed, with the exact nature of the test depending on the type of tube involved.

For the usual transmitting or receiving tube, test instructions should specify voltages for filament, plate, control-grid, screen-grid, and suppressor-grid as required to observe filament, plate, control-grid, and screen-grid currents. Emission, plate resistance, amplification factor, and mutual conductance should be determined; furthermore, it is desirable that interelement capacitances be measured also.

Cathode-ray tubes should be checked for light output, line width, deflection sensitivity, focusing voltage, leakage, gas ratio (or cross), interelement voltage breakdown, and anode currents.

Specifications for dynamic testing should include load resistance (or impedance), signal voltage, and power output at normal and reduced filament voltage. In addition, specifications should give operating voltage and current ranges for all other tube elements.[1]

Measurement of Interelectrode Capacitances

For the measurement of capacitances of 1 $\mu\mu$f or less, several methods are available. Perhaps the most accurate procedure uses a precise capacitance bridge. Another satisfactory method uses a vacuum-tube voltmeter to measure the voltage developed across a capacitance at a fixed frequency. Alternative methods are:

(1) Capacitance can be measured as part of a resistance-capacitance discharge circuit in which the tube capacitance discharges through a known resistance. Since $C = t/R$, the capacitance is easily determined. Both time (in the order of microseconds) and resistance (in the order of megohms) can be determined with reasonable accuracy.

(2) Capacitance can be measured as the terminating impedance of a coaxial transmission line. The reactance is measured by placing the tube in the transmission line as a terminating element. The line is then tuned to resonance by varying its length.[2]

Mechanical Performance Tests

Tubes must perform satisfactorily and must possess reasonable life; in addition, they must be rugged. This does not imply that it is permissible to play hockey with a two-inch u-h-f transmitting tube. On the other hand, it should not be necessary to transport the tube in a plush-lined case. The usual points of mechanical weakness can be divided into four main headings:

(1) Metallic bodies (filaments, grids, plates, etc.)
(2) Metallic joints (welds)
(3) Glass bodies (glass envelopes, beads)

QUALITY ENGINEERING
Articles to Come

Shrinkage Analysis in Tube Manufacture
DECEMBER 1944 ELECTRONICS

Quality Control in Tube Manufacture
JANUARY 1945 ELECTRONICS

ENGINEERING in Tube Manufacture

Testing of random samples can indicate when vacuum-tube production deviates from quality standards. Procedures given, applicable to other products as well, cover static and dynamic performance tests, life tests, mechanical tests, and checking of appearance

(4) Glass joints (either glass-to-glass or glass-to-metal)

Among the methods used for checking the mechanical durability of the tube are: 1. Bump tests; 2. Vibration tests; 3. Thermal shock tests.

In a bump test, a pendulum of prescribed weight and length is allowed to strike the tube, which is so suspended that it swings freely on impact. The tube is then tested for mechanical failure, static characteristics and interelement capacitance (revealing changes in electrode spacings).

The vibration test is essentially the same as the bump test. Instead of causing acceleration through impact, the tube is placed on a shake table and is subjected to acceleration values that are several times that of gravity. Both of these tests can be made with voltages on the elements, so that results can be observed on a cathode-ray-tube oscilloscope. In this way, temporary interelement shorts and undue voltage excursions can be observed.

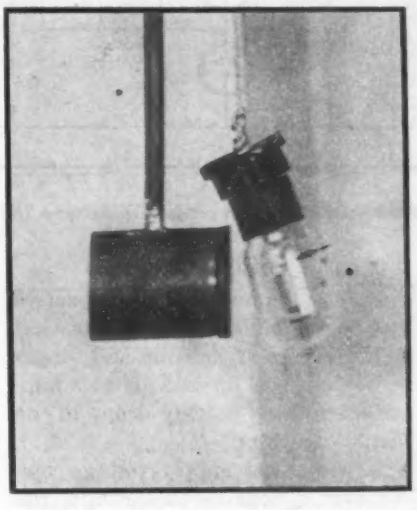
Thermal shock tests are concerned with the condition of the glass. In general, they reveal improper annealing or defective sealing.

The foregoing are the most common mechanical performance tests. It is possible to make as many tests as there are mechanical performance weaknesses.

Life Testing of Tubes

Tube life can be determined on the basis of either static or dynamic performance. In any event, the life will depend (among other factors) upon: 1. Filament voltage; 2. Tube operating temperature; 3. Amount and nature of the free residual gases in the tube and in the metallic parts.

Within a thoriated tungsten filament, thorium is diffused to and evaporated from the surface at a definite rate. The ideal filament voltage is one which causes a current flow of such magnitude that the heat produced establishes an equilibrium between these two rates.[a]

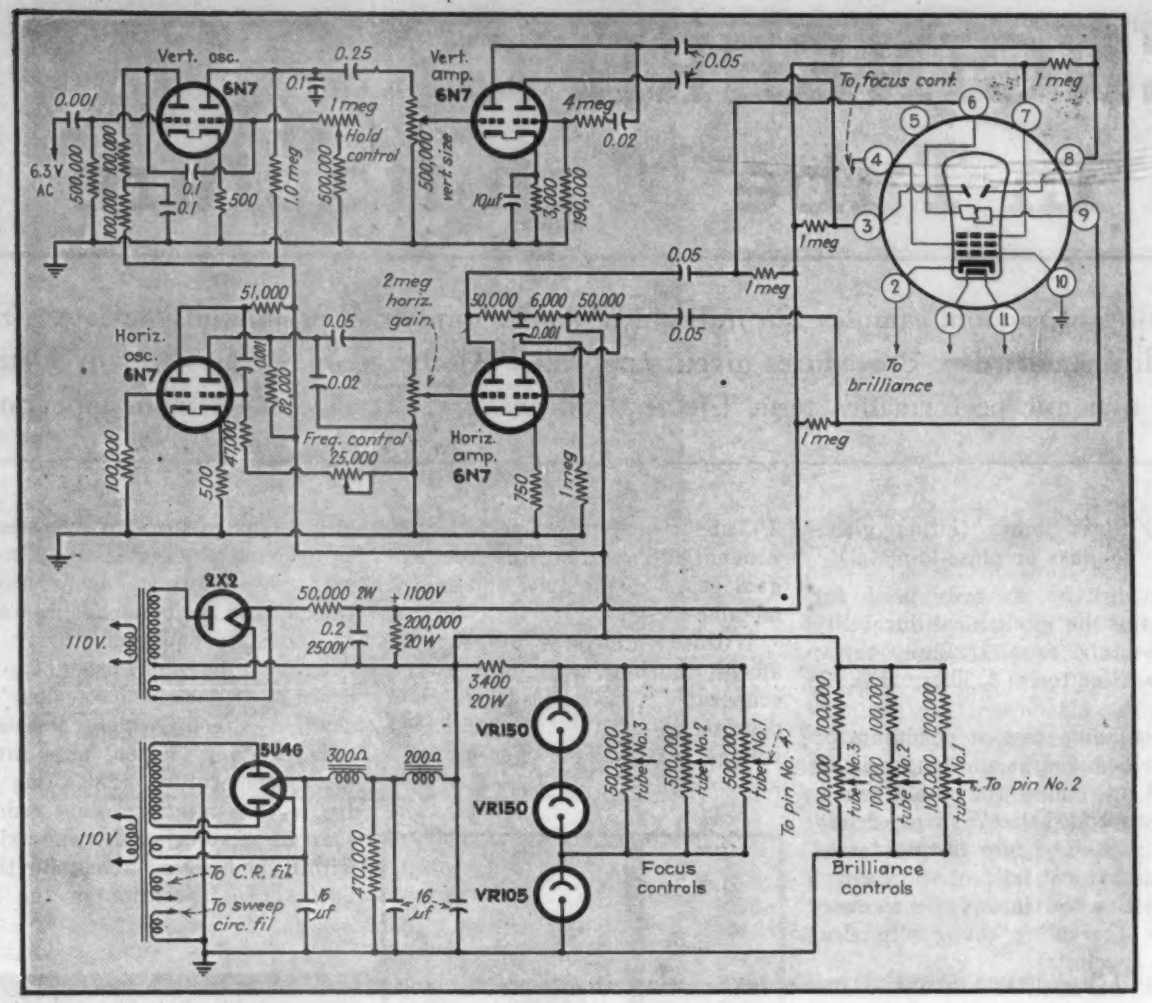


Type 24G tube an instant after being struck by the pendulum hammer used in the bump test

If the filament temperature is too low, insufficient emission will result. If filament temperature is too high, the rate of evaporation will exceed the rate of diffusion. Under this condition, the surface is stripped of its thorium and soon acquires the properties of a pure tungsten emitter, which is about 1/1000th the emission of a thoriated tungsten filament operated at equivalent temperature. As a result, the emission drops rather sharply and the tube ends its useful life abruptly and prematurely.

Such a tube can be brought to life again by means of the so-called "hot shot" treatment, which consists of operating the filament at a rather high temperature (2800 deg K) for a few minutes. This reduces some of the thoria (thorium oxide) within the filament to metallic thorium. Then, operation of the fila-

Laboratory assistant placing a type 24G tube in a static life test rack



Schematic circuit of three-position life test set for use on type 2AP1 cathode-ray tubes

ment at a lower temperature (2200 deg K) diffuses the newly reduced thorium to the surface. However, life obtained by rejuvenation is not a true test of life, but rather is a test of the renewing process.

It has been pointed out that the voltage at which a filament is operated determines its temperature. Temperature determines the fraction of the surface which is covered with a monatomic layer of thorium. Emission may drop below acceptable limits as the fraction of the covered surface is reduced. Since good life depends upon good emission, any factors which disturb or deteriorate the emissive properties of the filament contribute to the early demise of the tube. Operation at excessive filament voltage is one such factor.

Another factor which can result in reduced emission is the presence of excessive amounts of oxygen in the tube. Should this highly-active gas be available to form a chemical union, layers of thorium and tungsten oxides are formed. If this happens, emission quickly drops to the vanishing point.

If the power supply voltage varies over a considerable range, the life test will operate at various temperatures; in other words, anode and filament power dissipation will vary. It is therefore necessary that the power line voltage for life test equipment be regulated within close limits.

Complete and carefully prepared records should be kept of all test conditions and causes of failure. This latter point cannot be overemphasized since one of the primary objects of all life tests is to reveal the weaknesses which cause tube failure. For example, to state that a cathode-ray tube failed due to low light output is not enough; it is much more significant to point out that the low light-output was caused by a deteriorated cathode surface which resulted from the failure of a metal-to-glass seal.

The tube that performs properly is interesting and indeed welcome; nevertheless, it is the defective tube that uncovers weaknesses and helps us evolve new and better production techniques.

Other Tests

Samples should be selected and tested at periodic intervals, in order to ascertain the life of the shipped product. Factory engineers, design engineers, and persons responsible for maintaining production should be advised of all failures occuring in non-experimental tubes. All innovations in processing or structure should be successfully life-tested before becoming a regular

part of the manufacturing procedure.

Appearance Tests

A sizeable quantity of tubes should be selected at random from the packing room and should be examined for appearance. This inspection should answer the following questions:

(1) Is the tube clean?
(2) Is the tube identification brand clean and legible?
(3) Is the company trademark clean and legible?
(4) Are the base pins neatly soldered? Has extra flux been wiped away?
(5) Is the tube base on straight?
(6) Are the critical dimensions within specification?
(7) On the basis of the perfect tube being rated as 100 percent, what is the rating of the average of these tubes?

The basic purpose in making this type of examination is to rate the tube's appearance from the standpoint of saleability.

Maintenance of Primary Standards

It is inadequate to say that the vacuum-tube industry sells "tubes". We are offering measurements when we offer tubes. Some assurance must be given that the meters which check those measurements are correctly calibrated.

Tubes are saleable because they have certain characteristics—characteristics which are measureable by meter. Quality, as determined by electrical testing, implies the use of meters, and the testing is no better than the meters that perform the work. Improperly calibrated meters give rise to three risks:

(1) The possibility that acceptable tubes may be rejected.
(2) The possibility that rejectable tubes may be accepted.
(3) The possibility (almost certainty) that the quality will be indeterminate.

Proper calibration of test meters is normally a function of a meter maintenance unit, acting under the jurisdiction of an equipment section. This meter-maintenance unit will generally have a set of secondary standards. However, the quality control activity is so definitely tied up with measurement problems that it is advantageous to have the primary standards retained by the quality engineering division.

Certified standard cells, high-precision potentiometers, volt boxes, current and voltage transformers, highly sensitive galvanometers and accurate wavemeters are a few of the primary standards which should be available to the quality control engineer. Then, when a question comes up involving the accuracy of factory readings, unquestionable evidence can be produced by the quality engineering laboratory. Unless a standards laboratory is set up to do the job, the quality engineering department should act as the "Bureau of Standards" for the factory.

With a test procedure set up, the next step in utilization of quality engineering is analysis of the test results to determine exactly where the trouble is when shrinkage (loss during production) exceeds permissible manufacturing limits. This subject will be taken up in the next issue, and will be followed by the final article covering process control charts and other statistical methods of controlling quality during manufacture.

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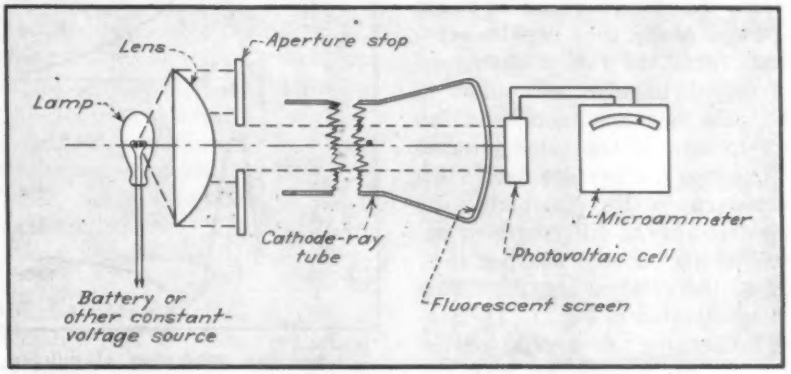
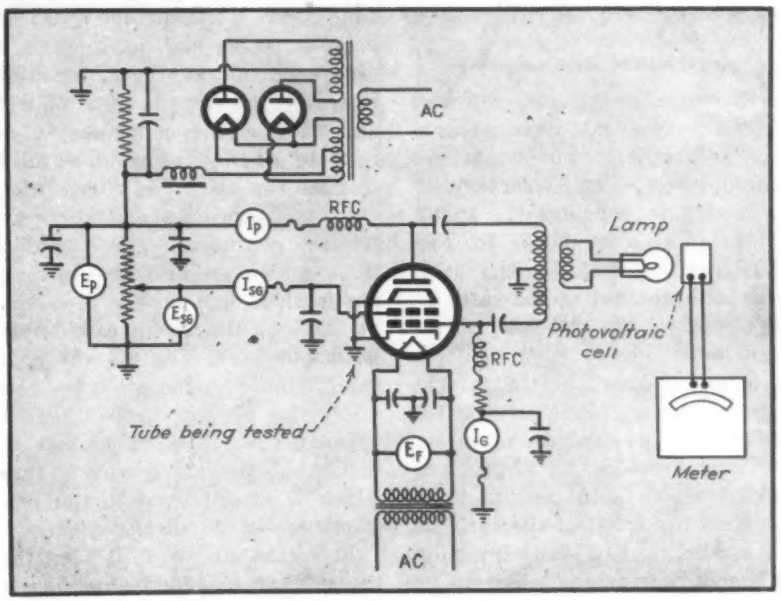
(2) Nergaard, L. S., A Survey of Ultra-High-Frequency Measurements, *RCA Review*, Oct., 1938.
(3) Koller, L. R., "Physics of Electron Tubes," McGraw-Hill Book Co., New York.



Arrangement used for measuring light transmission of a cathode-ray tube screen



Simplified schematic of oscillator used to determine power output of a beam-power tube. The circuit is essentially a Hartley oscillator in which the inter-electrode capacitances of the tube under test serve as the capacitive elements of the tank circuit. The cathode is grounded to complete the plate circuit

DIFFERENTIATING and

Engineering and laboratory applications of differentiating and integrating circuits are described, including anti-hunting circuits for servo mechanisms and other control systems. Practical circuits are developed from a mathematical basis and test results are given

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THE need for an electrical circuit to differentiate a wave of voltage with respect to time often arises in various types of problems. As an example, it is desired to determine the sequence of arrival of several overlapping impulses. The sharper the impulses the more easily they can be separated. Since the rate-of-change of a received impulse will start at zero, rise to a maximum, and fall back to zero in the same interval of time that the impulse itself rises from zero to its maximum, the wave-front of the differentiated impulse is shorter and sharper than that of the original impulse. This is demonstrated in Fig. 1. The signal announcing the arrival of the original impulse can be made as short and sharp as desired by taking successive derivatives of the original impulse by cascading several differentiating circuits.

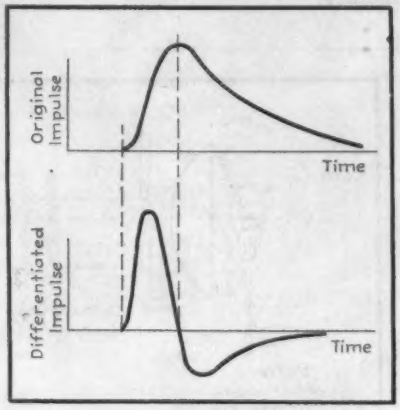


FIG. 1—One application of differentiating circuits is to sharpen impulses

Anti-Hunting Applications

Differentiating circuits can also be used to prevent servo-mechanisms and other control systems from hunting. As an elementary example of this, consider the speed-governing system shown in Fig. 2(a). The speed of the turbine is to be held constant at the value N_0 which makes the voltage of the magneto-tachometer equal and opposite to a selected portion of the battery voltage. If it is not, the difference voltage drives a motor (probably through an amplifying system) which actuates the valve to correct the speed of the turbine.

A sudden load of short duration can cause the turbine speed to be low, as shown at the time t_1 on the curves of Fig. 2(b). Under this condition the difference voltage drives the motor to open the valve, accelerating the turbine until the time t_2. At t_2 the turbine speed has been corrected and, as there is no difference voltage, the motor stops. However, the valve is open too wide and the turbine continues to accelerate, so that the motor reverses to close the valve. At t_3 conditions are set to reverse and the oscillations continue. These oscillations, which are desirable in many applications, are usually kept small by damping the motion of the valve with a dashpot. The valve is in its equilibrium position when the rate-of-change of its displacement is greatest. The dashpot opposes the motion of the valve with a force which is proportional to the rate-of-change of its displacement.

From the curves, it is seen that the difference voltage also has its greatest rate of change when the valve is at its equilibrium position. This offers the possibility of introducing an electrical circuit to produce an effect similar to the dashpot. Let a voltage proportional to the difference voltage be put into a differentiating circuit, and the output of the differentiating circuit be placed in series with the voltages of the speed-control circuit of Fig. 2(a). By adjusting the magnitude of this voltage, the oscillations may be critically damped, over damped, or under damped, whichever is the more desirable.

Research Applications

Integrating circuits can be used in many measurement and research problems where the summation of some function is required at every instant. Mechanical methods of integration are most convenient when the function being integrated is fairly constant and uni-directional. However, for alternating and rap-

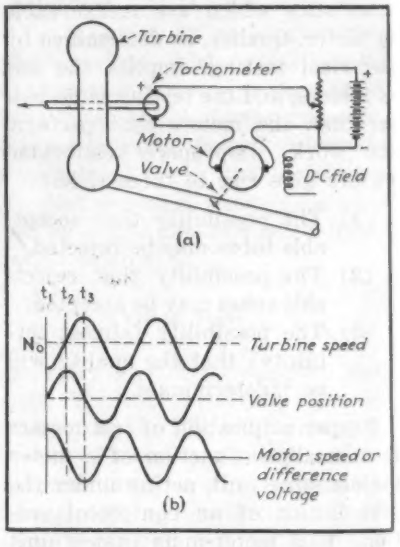


FIG. 2—Instead of damping the valve in the turbine steam-line with a dash pot, a differentiated voltage can be applied to the motor to prevent the system from hunting

INTEGRATING CIRCUITS

idly changing variables, electrical integrating circuits such as are described in this paper are more satisfactory.

A common application is in oscillographic studies of magnetic flux. To obtain an oscillogram of the magnetic flux linking a search coil, the voltage induced in the search coil can be applied to an integrating circuit, and the output of the integrating circuit delivered to the oscillograph. The integrator voltage is proportional to the flux because the induced voltage is proportional to the rate of change of flux;

$$E_{ind} = -N\frac{d\phi}{dt} \times 10^{-8} \text{ volts} \quad (1)$$

The flux is then proportional to the integral of the induced voltage:

$$\phi = \int d\phi = -\frac{10^8}{N}\int E_{ind}\, dt \text{ lines} \quad (2)$$

Figure 3 shows hysteresis loops that were taken using an integrating circuit. These loops and the associated exciting current waves are for the iron-cored inductor of a series *R-L-C* circuit experiencing subharmonic oscillations.[1]

Similarly, an oscillogram of the displacement of a moving object can be obtained with a dynamic pickup if the object moves the conductors of a coil perpendicular to a magnetic field. The voltage induced in the coil is applied to the integrator, and the voltage from the integrator is applied to the oscillograph. This integrated voltage is proportional to displacement because the induced voltage is proportional to the velocity of the coil;

$$E_{ind} = BLV \times 10^{-8} \text{ volts} \quad (3)$$

Displacement is then equal to the time integral of the velocity.

$$\text{Displacement} = \int (\text{Velocity})\, dt = \frac{10^8}{BL}\int E_{ind}\, dt \text{ cm} \quad (4)$$

This is useful in various mechanical problems, such as studying the vibration of a piece of machinery, or following the motion of a moving part such as the intake valve on a diesel engine.

In physiological studies, nervous activity or other responses can be integrated to compare total activity or response under various conditions. If the signal being integrated is not uni-directional, it is usually necessary to rectify the signal before it is integrated.

Integrating circuits can be used in many other applications requiring the totalling or the summation of some variable.

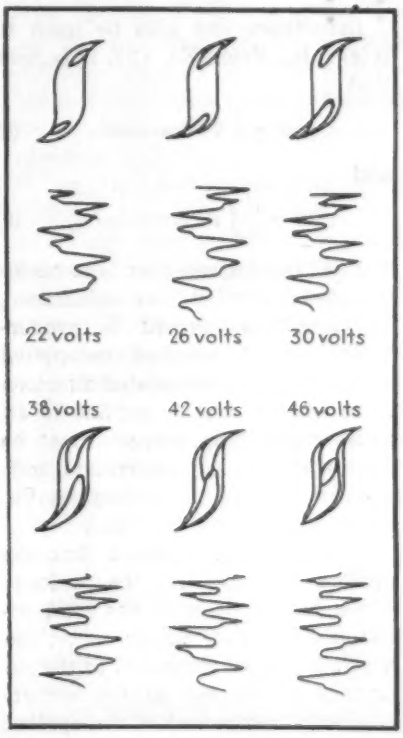
Inductance as a Differentiating Circuit Element

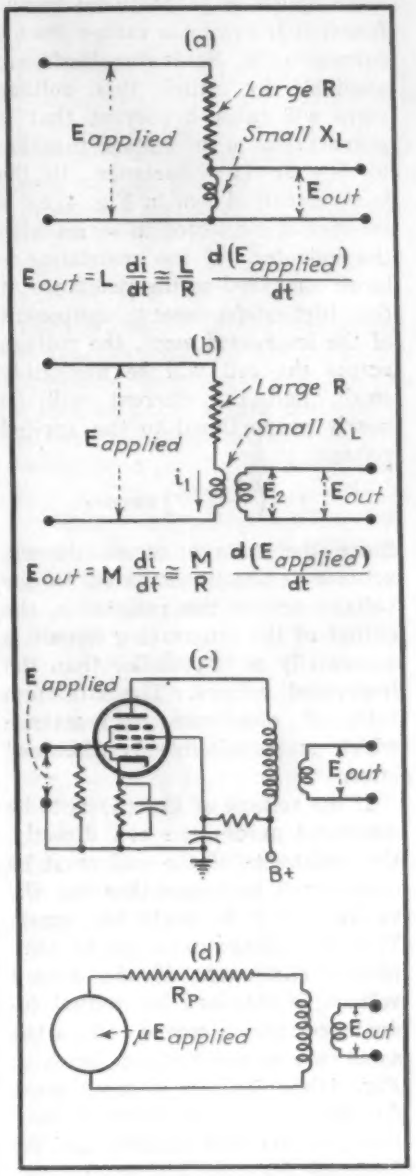
To perform differentiation electrically, the function which is to be differentiated must first be made proportional at every instant of time to some electrical quantity. This can then be impressed on some circuit element which yields another electrical quantity which is proportional to the derivative of the impressed quantity.

The voltage applied to an inductance is

$$E_L = L\frac{di}{dt} \text{ volts} \quad (5)$$

If the current through the inductance can be made proportional at every instant to the function





ABOVE

FIG. 4—(a) An inductance in series with a large resistance forms a voltage differentiating circuit. (b) The use of a mutual inductance to couple to the output improves the differentiating action of the circuit. (c) A pentode replaces the series resistance of the above circuits, and also provides amplification. (d) The equivalent circuit of (c)

AT LEFT

FIG. 3—Exciting current and resulting hysteresis loops for an iron-cored inductor in an *R-L-C* circuit undergoing subharmonic oscillations. The hysteresis curves were obtained by differentiating the voltage induced in a search coil

which is to be integrated, the voltage across the inductance will be proportional to the derivative of the function.

In general, however, a voltage wave which is proportional to the function is available rather than a current wave. Several methods are available by which this voltage wave will cause a current that is proportional to the voltage function to flow in the inductance. In the basic circuit shown in Fig. 4(a), a resistor is connected in series with the inductor. If the resistance is large compared to the reactance at the highest-frequency component of the impressed wave, the voltage across the coil will be negligibly small, and the current will be nearly proportional to the applied voltage:

$$i \cong \left(\frac{E_{applied}}{R}\right) \text{amperes} \qquad (6)$$

Since the voltage across the reactance is small compared to the voltage across the resistance, the output of the integrating circuit is necessarily much smaller than the impressed voltage. The minimum ratio of resistance to reactance which is permissible is discussed later.

If the voltage of Eq. (5) is to be measured across the coil directly, the resistance of the coil must be quite small to insure that the iR_L voltage drop is negligibly small. This iR_L voltage drop can be completely eliminated if the output voltage is obtained by mutual inductance from a second coil on the same core as the first, as shown in Fig. 4(b). This is a much more desirable circuit in most applications, because the resistance of the first coil does not distort the output wave-form. It simply aids the series resistor in making the current proportional to the applied voltage. The output voltage induced in the second coil is

$$E_2 = M\frac{di_1}{dt} \text{ volts} \qquad (7)$$

Its magnitude can be adjusted by adjusting the turns on the secondary coil.

The current through the inductance can also be made proportional to the applied voltage by using a tetrode or pentode vacuum tube. The plate current of these tubes is almost independent of the plate voltage. If the signal to be differentiated is applied to the control grid, the resulting plate current will be proportional to the signal and nearly independent of the load impedance. As shown in Fig. 4(c) and 4(d), this is equivalent to substituting the plate resistance of the vacuum tube for the series resistance used in the basic circuits of Fig. 4(a) and 4(b). These circuits offer two advantages over using the tube as a conventional amplifier with the basic circuit: First, more voltage is available at the output for a given input voltage; second, a greater swing of plate voltage is permissible for a given battery voltage.

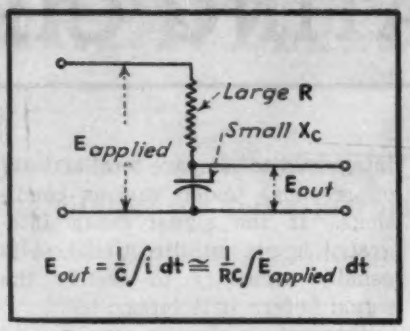


FIG. 5—A large inductance in series with a small resistance forms an integrating circuit

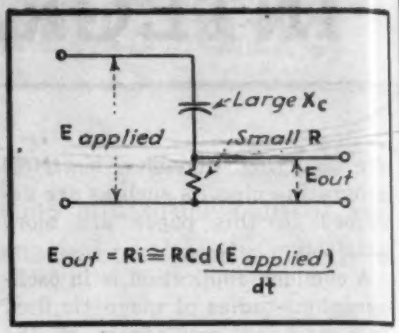


FIG. 6—If the voltage to be differentiated contains only a-c components, a capacitor can serve for differentiating

Inductance as an Integrating Circuit Element

Inductance can also be used to integrate. From Eq. (5), it is seen that

$$di = \frac{1}{L}E_L\,dt \text{ amperes} \qquad (8)$$

and

$$i = \frac{1}{L}\int E_L\,dt \text{ amperes} \qquad (9)$$

Thus if the voltage that is to be integrated is applied to an inductance, the resulting current is proportional to the integral of the applied voltage. If the integrated function is to be amplified or applied to an oscillograph, this current must be converted into a proportional voltage by passing it through a resistance as shown in Fig. 5.

If it is to be assumed that the applied voltage is the voltage across the inductance, the total resistance of the circuit must be negligibly small compared to the reactance of the coil at the lowest-frequency component of the applied voltage. This means that the output voltage is again very much smaller than the impressed voltage.

The inductance is best suited for use as a differentiating and integrating circuit-element when this portion of the circuit must carry a direct component of current. It is unsatisfactory for use in many applications. At low frequencies, a large coil is necessary to give a reactance which is high compared to its own resistance. At high frequencies, the current through the distributed capacitance of the coil becomes large, so that Eq. (5) and (7) are no longer valid. If an iron core is used, an air-gap should be inserted to insure that the self inductance and the mutual inductance remain essentially constant.

Capacitance as a Differentiating Circuit Element

Because of their low cost, small size and freedom from residual resistance and inductance, capacitors are generally more satisfactory than inductors for differentiating or integrating circuit elements. However, they cannot carry direct components of current, as the inductors do, which is a disadvantage in some applications.

The charge on a capacitor of C farads and the current through the capacitor are

$$q = CE_c \text{ coulombs} \qquad (10)$$

$$i = \frac{dq}{dt} = C\frac{dE_c}{dt} \text{ amperes} \qquad (11)$$

This enables the capacitor to be used as a differentiating circuit element. If the function to be differentiated is proportional to the voltage applied to the capacitor, the resulting current through the capacitor is proportional to the derivative of

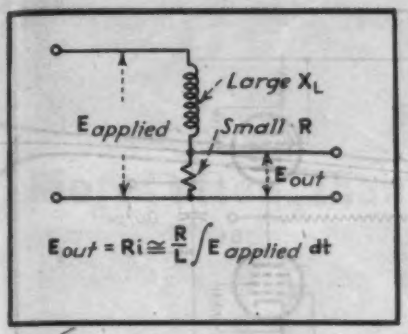


FIG. 7—Compare this capacitance integrating circuit with the inductance differentiating circuit of Fig. 4(a)

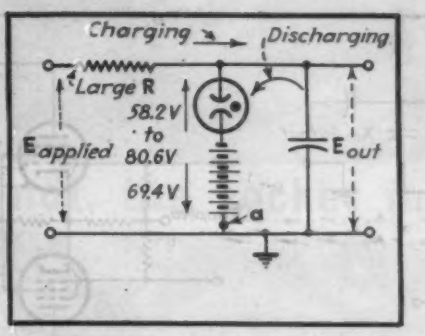


FIG. 8—Neon lamp circuit used to periodically discharge the integrating capacitor when charging is unidirectional

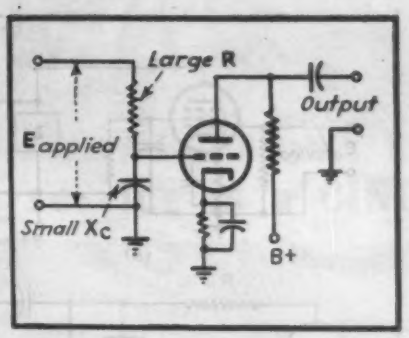


FIG. 9—Basic integrating circuit using a capacitor and amplifier. The signal source provides a d-c path to ground

the applied voltage. As shown in Fig. 6, a small resistance can be placed in series with the capacitor to give an output voltage proportional to this current.

Capacitance as an Integrating Circuit Element

The charge, q, which is delivered by a current is, from Eq. (11),

$$q = \int i\,dt \text{ coulombs} \qquad (12)$$

Any circuit element which yields a measure of the charge when a current is passed through it can be used in an integrating circuit. An example of this was the old electrolytic ampere-hour meter, which measured the ampere-hours taken by a customer in terms of the change of weight of a plate in an electrolytic cell.

Several circuits, which can be adapted for use over a wide range of frequencies, measure the charge delivered by the current in terms of the voltage across a capacitor. From Eq. (10) and (12), it is seen that the voltage across a capacitor is

$$E_c = \frac{1}{C}\int i\,dt \text{ volts} \qquad (13)$$

Thus if the current through the capacitor is made proportional at every instant to the function which is to be integrated, the voltage across the capacitor is proportional to the time integral of the function. To obtain a current which is proportional to the function from a voltage which is proportional to the function, connect a resistor in series with the capacitor as shown in Fig. 7. If the resistance is large compared to the reactance of the capacitor at the lowest-frequency component of the impressed wave, the voltage across the capacitor will be negligibly small, and the current will be nearly proportional to the applied voltage at every instant.

$$i \cong E_{applied}/R \qquad (14)$$

If the current being integrated is uni-directional, or has an average value predominantly in one direction, the voltage across the capacitor will rise continuously, so that it will not remain small compared to the voltage across the resistor. Under these conditions, the capacitor can be discharged through a thyratron or glowtube when its voltage reaches a predetermined value. The discharge current can be made to operate a counter by passing it through a small resistance inserted at a in Fig. 8, and applying the resulting positive pulse of voltage to the grid of a thyratron. The plate current of the thyratron can actuate a solenoid-operated counter. In this way the counter indication times the charge accumulated before each discharge gives the total integral.

The bias battery used in series with the gas-glow tube should have a voltage approximately half-way between the voltages at which the glow tube ignites and extinguishes. With this bias voltage, the average leakage through the tube and capacitor will be zero. Circuits of this kind can be used to measure very small currents by integrating the current to evaluate the charge delivered in a measured interval of time.

Practical Circuits

As with the inductor, the output voltage from circuits using a capacitor to integrate is much smaller than the applied voltage. If the output voltage is to be amplified by a conventional amplifier, the voltage across the capacitor should be applied directly to the grid of the amplifier, without a grid resistor, as shown in Fig. 9. A grid resistor would be in parallel with the capacitor, and would tend to disturb the integral relationship between current and charge. To prevent the grid from floating, the input circuit should provide a d-c path to ground.

As was discussed earlier, the plate resistance of a tetrode or pentode vacuum tube can be substituted for the series resistor used in the basic circuit of Fig. 7. The ideal load impedance, Z, in Fig. 10(a) and 10(b) would carry only the direct component of the plate current, so that all variations of the current which were caused by the signal on the control grid would be forced to flow through the capacitor. The best impedance to use depends chiefly on the frequency of the signal being integrated. Since the signal component of the current in Z should be small, the impedance of Z must be large compared to the reactance of the capacitor at the lowest-frequency component of the impressed wave.

A resistor is generally unsatisfactory for use as the load impedance Z, because if it is large enough to prevent the flow of an appreciable portion of the signal current, an excessive battery voltage is required to give a reasonable plate voltage. Since a pentode vacuum tube with constant control-grid voltage carries a plate current which is nearly constant and independent of plate voltage, a pentode could be used for this load impedance, as shown in Fig. 10(c);

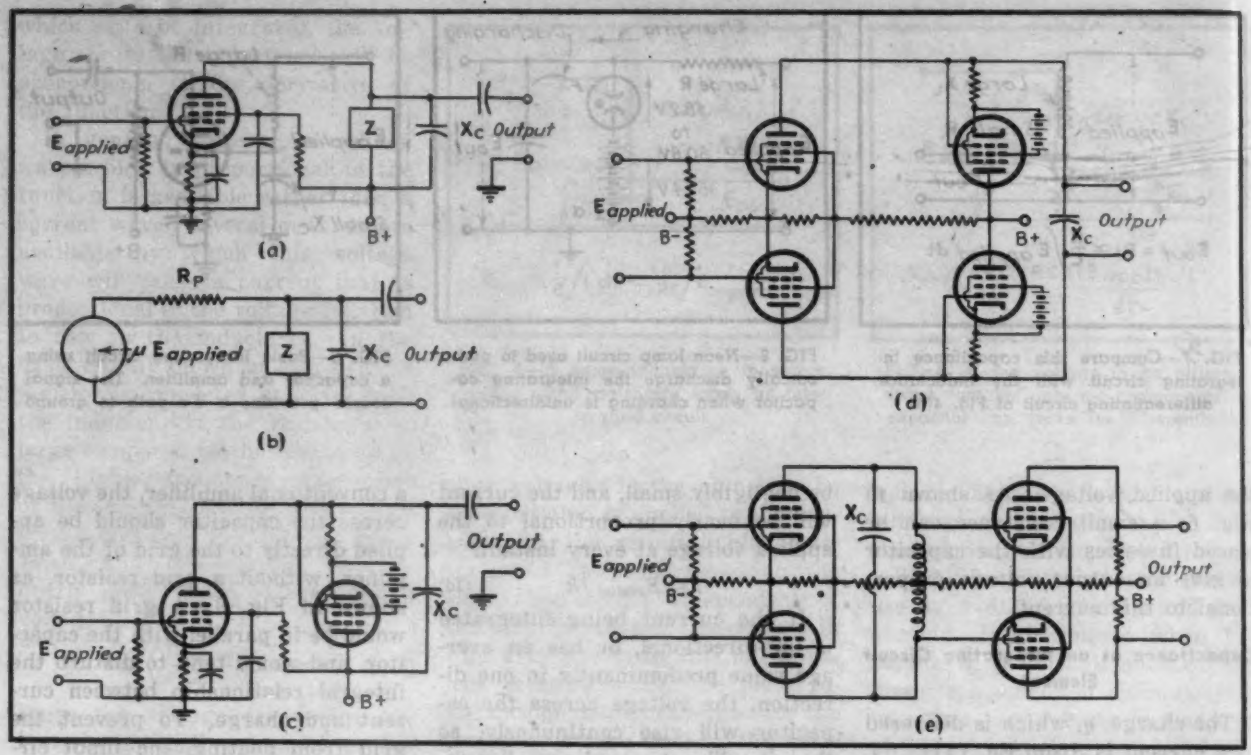


FIG. 10—(a) The large resistor of Fig. 7 can be replaced by a pentode if integrating capacitor X_c can be bridged by an impedance Z which will pass direct current, but will have a very high (ideally infinite) impedance to alternating current. The equivalent circuit is shown at (b). (c) A pentode can be used for the impedance Z. (d) Push-pull version of the circuit of (c) eliminates the need for by-pass capacitors, thereby providing unlimited low-frequency integration. Where the wave to be integrated does not contain an extremely low-frequency component, the circuit at (e) can be used. The inductor is the impedance Z of (a). The circuit shown has been designed for direct coupling to an amplifier stage

this is equivalent to using the plate resistance of the pentode for a load impedance. If the cathode bias resistor is made large, its degenerative effect will help maintain a constant current through this tube. This circuit is somewhat similar to the Schmitt[2] amplifier.

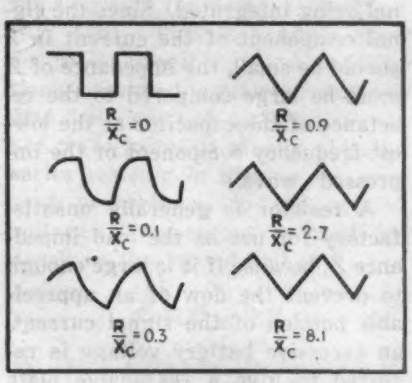


FIG. 11—Using the integration circuit of Fig. 7, with $R = 10{,}000$ ohms and the impedance of X_c at the lowest frequency component of the applied square wave related to R as tabulated above. It is seen that a ratio of $R/X_c = 8$ provides effectively perfect integration

If these circuits use tubes in push-pull, as shown in Fig. 10(d) and 10(e), they are much more stable, and have the many other advantages of push-pull circuits. Wider voltage swing is permissible. Distortion from non-linearity of the characteristics is balanced out. No net direct current magnetizes the core of an iron-core inductive load. No net direct voltage appears across the integrating capacitor.

Tests

The output of the various circuits discussed in this paper is only approximately proportional to the derivative or the integral of the impressed quantity, depending on the ratio of the selected reactances and resistances. The differentiation or integration becomes more accurate as the impedance from which the output voltage is taken is made smaller. However, the output voltage is also made smaller as this impedance is decreased.

To serve as a guide in selecting the ratio of resistance to reactance, the R-C integrating circuit shown in Fig. 7 was tested with a rectangular wave input. The resistance was 10,000 ohms. Since

$$\int K\,dt = K\,t \qquad (15)$$

the integral of the rectangular wave should be a triangular wave.

For the first curve of Fig. 11, the capacitance was set at zero, so that the square-wave input appeared across the output. For the following curves, the capacitance was set to give the values of R/X_c that are indicated, where X_c is calculated for the lowest-frequency component of the square-wave input. It was necessary to increase the gain of the oscillograph to hold the pattern at approximately the same size when the capacitance was increased.

These tests indicate that a ratio of R to X greater than eight is satisfactory for most oscillographic work.

References

(1) Spitzer, Charles F., Subharmonic Response in Non-Linear Series Circuits (paper, Yale University, New Haven, Conn.). Accepted for publication by *Jour. Applied Physics*.

(2) Schmitt, Otto H. A., A Method of Realizing the Full Amplification of High-Mu Tubes, *R. S. I.*, December, 1933.

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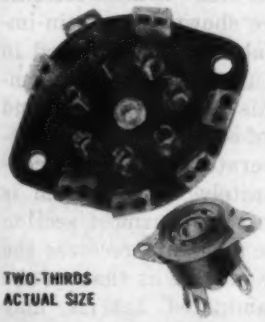

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INDUSTRIAL CONTROL

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Electronic Indicator for Oil Refining Plant

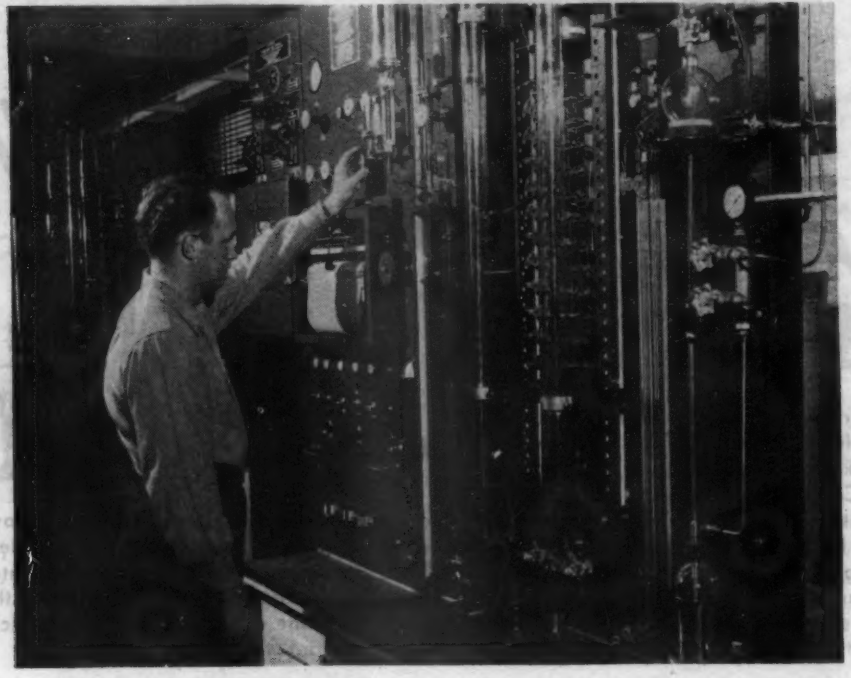
IN MODERN OIL REFINERY methods, accurate boiling points of the various vapors, to be separated in fractionation, must be pre-determined in the laboratory. This is now accomplished with electronic equipment.

The instrument, manufactured by Brown Instrument Co., is a continuous balance potentiometer pyrometer, which utilizes electron tubes to magnify a small temperature gradient. This is mechanically connected to a conventional Brown recording potentiometer. A special high-sensitivity fine wire thermocouple, consisting of six individual couples spaced about one-half inch apart, is located in the reflux zone of the fractionating column. The electromotive forces produced by these thermocouples are amplified by the electron tubes and recorded continuously by pen on a time-temperature strip chart.

The instrument finds particular application at present in the rapid and accurate analyses of four and five-carbon hydrocarbons. The special thermocouple covers all possible positions of a wandering condensation ring, which is known to vary several inches up or down in the fractionating column. Thus the true boiling point of a compound is accurately recorded no matter which couple is located in the coldest zone. This could never be accomplished by a single-junction thermocouple. The electronic recorder and the special Podbielniak fractionating column make possible rapid and accurate separation of compounds whose boiling points are only one and one half degrees apart, a feat which cannot be accomplished by the older type of apparatus.

The new development considerably reduces distilling time, with increased accuracy, and opens up a new field in fractional distillations. To accomplish the perfect blendings necessary in producing the new "100-plus" octane gasoline used in war planes, Richfield Oil Corp. has installed this electronic equipment in its newly expanded refinery near Los Angeles.

Towers of the alkylation unit at the Richfield refinery where electronic apparatus is used to indicate the boiling point of the various vapors. In the unit above, iso-pentane and iso-butane are combined into alkylate, the blending agent that puts long range into super-octane aviation gasoline



The boiling point of any hydrocarbon fraction an oil refiner desires to separate can be determined by electronic apparatus used in conjunction with this pilot fractionation tower recently installed at the Richfield 100-plus octane refinery. In the photo above, the engineer is adjusting the equipment while noting readings on the Brown instrument recorder

Electronic Heating in Textile Industry

TESTS CONDUCTED with electronic heating have shown that resin-impregnated fabrics may be cured in roll form. Curled selvages are eliminated by this form of drying, and uniformity of curing is obtained because temperature may be controlled accurately. Resin which is deposited on the innermost section of the fabric structure receives the same degree of heat as that on the outside. Laminated fabrics may also be cured in roll form.

Successful setting of twist in rayon and in nylon, handling yarn

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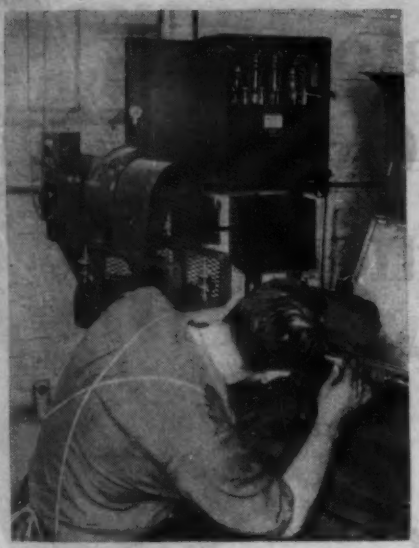
★Advt. No. 529—2nd Cov., 2 cols.—Electronic Industries—December, 1944
★Advt. No. 529-A—1 page, B&W—Electronics—November, 1944

on cones as large as 18 lb, was reported in ELECTRONICS for September, 1944.

Rayon cakes may also be dried with high-frequency equipment and can be handled in throwing mills after tinting or other processing operations where it is advisable to handle the yarn in cake form. This type of drying permits dyeing of rayon in cake form as the cakes may be dried either in a vacuum or at atmospheric pressure. Handling rayon in cake form eliminates skeining and other handling operations.

Electronic heat for drying in slashing operations holds possibilities, and other uses suggested by *Textile World* include the drying of heavy paper-makers' felts, heavy carpets, and other textile fabrics of great bulk, either in roll or in sheet form.



Electronic equipment in the cabinet supplies current to the shunt-wound motor at left. The pushbutton and speed control panel permits stepless operation over a 20-to-1 range while the grinder is running

30-Year Old Grinders Use Electronic Control

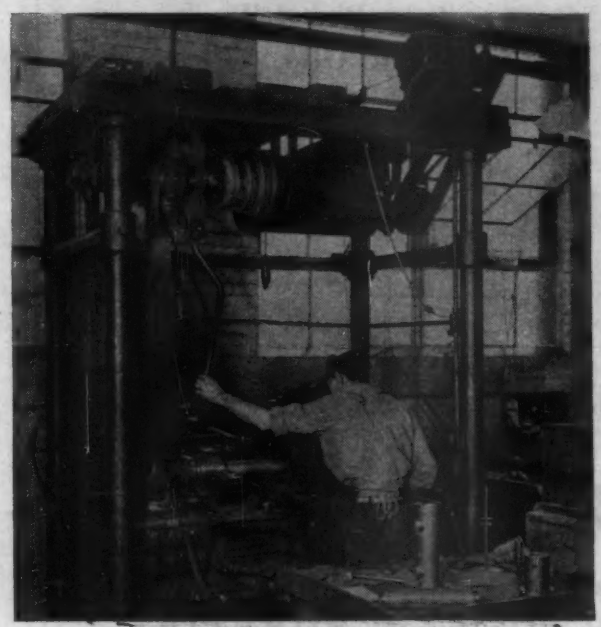
ELECTRONIC CONTROL can provide old machines with greatly improved operating characteristics when it is impractical to obtain new machine tools. Use of electronic motor drives on three 30-year old Heald grinders resulted in improved quality of precision finishing, vibration-free, stepless speed control over a 20-to-one speed range and better working conditions. The electronic drive (called Mot-O-Trol by Westinghouse) consists of an electronic rectifier to change alternating current to direct current, plus a d-c driving motor whose stepless speed is controlled by a potentiometer in the pushbutton station.

At the Axelson Manufacturing Company, problems in machining hardened pump liners were augmented by specifications which require a finished tolerance of 0.001 of an inch. The variation in liner sizes and materials used required grinding speeds over a wide, closely regulated stepless range in order to secure the desired tolerance and finish. This stepless quality in speed regulation permits the operator to choose just the right speed for size of hole material to be finished and grade and grit of the wheel. This helps to eliminate vibration and chatter marks in the work and gives a straight, true, round hole, an ideal condition for the honing operations that follows, for unless a perfect hole is presented to the hone it is apt to follow any irregular conditions of the ground hole.

Advantages

In addition to the advantages gained by providing stepless adjustable speed over a wide range, physical advantages were gained by new layouts of the machines. The three grinders were reset on a 35-degree angle with a saving in floor space of about one-third. Removal of all overhead pulleys, belts and shafting resulted in increased safety, improved illumination and elimination of vibration.

The time study department at Axelson reports that an appreciable



Before the advent of electronic control, these 30-year old Heald grinders were powered by belt-and-pulley drive that allowed only four speeds to machinists, occupied considerable space on the floor and blocked light and ventilation

After replacing the overhead countershaft with a Westinghouse electronic drive, additional working space, smooth speed change over a 20-to-1 range and pushbutton speed adjustment were provided for the grinders

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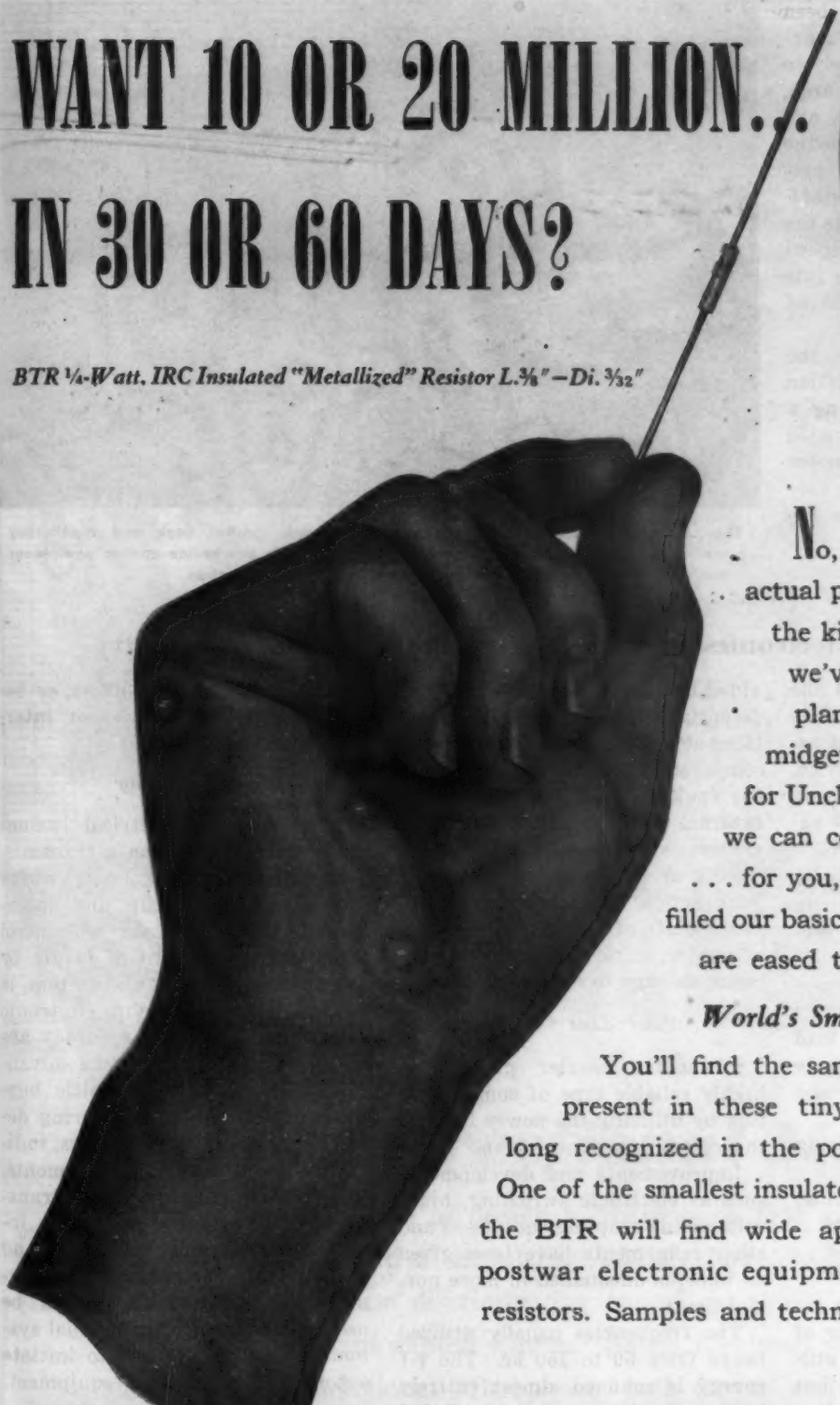

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saving in set-up time has been effected. V. Mancuso, works manager, believes this is due largely to the better illuminated working area, plus less complicated controls and speed changing apparatus on the grinders. The machinist can preset work speed either before starting work or change speed while the motor drive is running. Since speed change can be made smoothly, this can be done without danger of spoiling the work in process.

Besides a wide speed range, the Mot-O-Trol provides regulation that is effective in maintaining a constant motor speed with wide changes in load and limits the motor current to a definite maximum safe value. Speed control rheostats are so small that they can be built into a pushbutton station.

The photo above shows a Westinghouse electronic control desk and monitoring panel in a utility company office where it is used with power-line carrier equipment for supervisory control and fault correction

Five Uses of Electronics in the Electric Light and Power Industry

UTILITY COMPANIES have used the following five applications of electronic apparatus to extend and assure continuity of electric service, as well as conserve electric energy by reducing the time normally required to perform the operation.

1—Hi-speed power line carrier relaying to disconnect the circuit in case of faults in the protected section.

2—Power-line carrier intersystem communication.

3—Telemetering to expedite load dispatching or load control so as to assure adequate power when and where needed.

4—Supervisory control using power-line carrier equipment.

5—Meter and instrument testing, plus load-regulating equipment.

Carrier Relaying

Supplying more kilowatts on existing transmission lines is one of the many problems faced by utilities; not only more kilowatts, but better and faster clearing of line faults as well as high-speed opening and closing of circuit breakers. To do this, many schemes have been proposed. Electronic equipment has provided the answer in the form of power-line carrier relaying.

For good system operation, the high-speed clearing of faults on transmission lines is important. The best overall protection is provided by the method known as differential relaying, in which conditions at the two ends of the line are compared. This determines whether the fault is on the line section or external to the protected zone and assures simultaneous tripping of circuit breakers in 1 to 3 cycles. Such action is desirable from the standpoints of stability, continuity of service, quick reclosing, and minimum damage to equipment.

Power-Line Carrier

Power-line carrier provides a highly reliable type of communication by utilizing the power line for the communication channel.

Improvements and developments such as electronic switching, high-voltage line-coupling equipment and other refinements have been given an impetus unequalled in more normal times.

The frequencies usually utilized range from 50 to 150 kc. The r-f energy is confined almost entirely to the wire lines and not radiated into space as is common in radio broadcasting. This results in greater efficiency and makes it possible to transmit greater distances with less high-frequency energy.

An important application of power-line carrier is to provide reliable, high-quality voice communication between various points on the system, such as generating stations and dispatchers offices, or between dispatchers offices of interconnected systems.

Telemetering

Transmitting electrical values from remote points on a transmission system to a central point where they are summed up and interpreted, then sent back as control impulses to the point of origin or to any other point on the system, is called telemetering. With electronic apparatus, speed and accuracy are obtained, coupled with the advantage of not having parasitic burdens imposed on the measuring devices such as watthour meters, indicating and recording instruments.

Electronics has made the transmission of essential operating intelligence not only accurate and fast, but also brings together significant quantities which can be used independently for manual system control or totalized to initiate automatic load-control equipment.

Supervisory Control

Essential circuit breakers serving vital power areas, when disturbed by line faults, can be rapidly restored to normal service by power-line carrier systems. Apparatus switching at distant generator, transformer or conversion stations are all electronic functions.

The cost of older but well ac-

. . . in Directional Microphones

It is not enough to design a Microphone that merely converts sound waves into electrical impulses. A Microphone, to be truly useful in modern broadcasting, should be discriminating enough to accept wanted sounds —and reject unwanted sounds. Shure Research was the first to develop a single unit uni-directional Microphone, both crystal and dynamic.

Shure Research is the reason why practically every major broadcasting station uses the Shure 556 Unidyne. Shure Research is your assurance of postwar microphone superiority.

SHURE BROTHERS, 225 West Huron Street, Chicago
Designers and Manufacturers of Microphones and Acoustic Devices

SHURE MICROPHONES

. . . and Stancor will "step ahead" with postwar plans that not only will include units for most every communication and electronic apparatus, but will have inherent in those transformers, design technique which our extraordinary war production has demanded . . . Yes, Stancor is worth waiting for. So, before you specify —consult "Stancor for Postwar."

STANDARD TRANSFORMER CORPORATION
1500 NORTH HALSTED STREET, CHICAGO 22, ILLINOIS

cepted systems was a function of distance because of cables, telephone lines and other associated apparatus. Powerline carrier circumvents these costs by using existing transmission lines, leaving only terminal facilities to be installed. Since distance is no longer a controlling limitation, power-line carrier operates over greater distance than pilot wire, and permits wider application for this type of control.

Meter Calibration

Meter and instrument testing has always been an essential part of any electric light and power company. By the use of electronic apparatus, the human element is minimized and greater speed and accuracy are obtained.

Under the present system of manual testing of watthour meters, a good meter laboratory can average approximately 50 meters per eight hour day per man.

With visual types of electronic equipment, as many as 135 meters per day are being tested.

Load Control

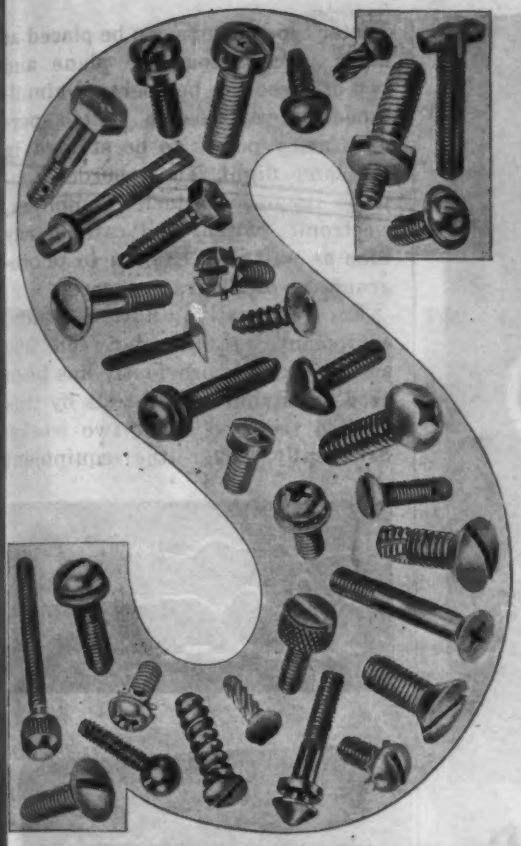
The bug-a-boo of indicating instrument and integrating meter testing has been load control. Automatic electronic load regulators now speed up instrument testing and increase accuracy with subsequent conservation of manpower. In addition, a reduction of electrical energy is effected by cutting down the time previously required to make the test.

That electronic devices have and will continue to perform an important part in the distribution and control of electrical energy was also predicted by Amos J. Germaine, of the electronics section of Westinghouse, in addressing members of the Iowa State Utilities Association at a recent meeting.

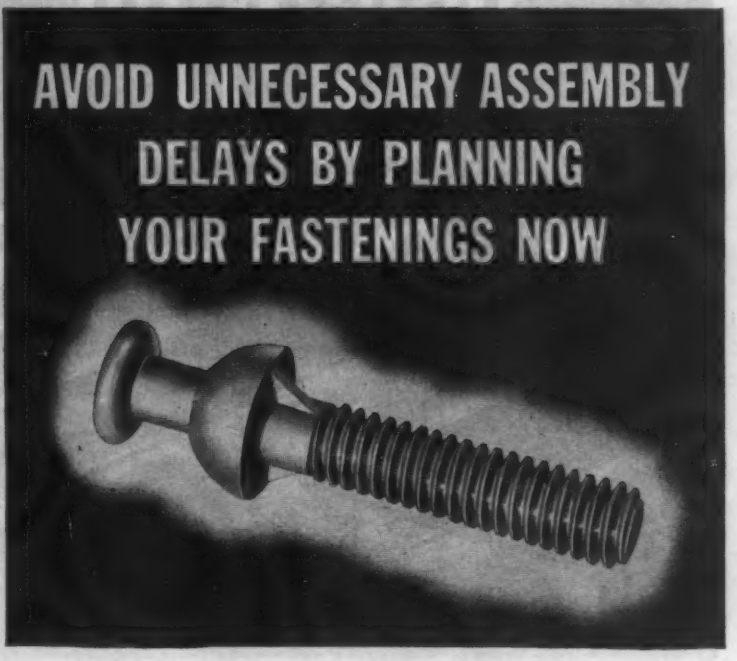
• • •

Portable Flutter Recorder for Planes

FLUTTER CAN BE, and in most cases is, avoided in designing planes. Especially in large planes, it rarely appears in the first model, in any severe form. Sometimes it appears in a particular plane after months of use where it did not exist in the prototype. With a new flight vibration recorder, velocity or acceler-



AVOID UNNECESSARY ASSEMBLY DELAYS BY PLANNING YOUR FASTENINGS NOW



"Cold-forging"—proof #25
...more each month

3 Standard Fastenings for Production Efficiency

1 Phillips Recessed Head Screws—The modern, effective, time-saving fastening device proven in tens of thousands of assembly lines. Other standard head styles are also available.

2 Self-Tapping Machine Screws—Eliminate separate tapping operations for fastenings to castings, heavy gauge sheet metal, and plastics. Also available with Phillips Recessed Head.

3 Washer-Screw Assemblies—When use of lock washers is indicated, the time-saving of pre-assemblies is obvious. Also available in standard slotted head styles.

Forethought, when your product is still in the design stage, can mean timely delivery of fastenings for that "long planned" fast assembly job. Your early and precise choice of fastenings—standard or special—may be vital to the fast and exacting assembly job required for an advantageous start on postwar production.

That's where Scovill comes in . . . our broad experience in fastenings and ingenuity in special design qualify us as specialists in the fastenings field. Let us help you determine the best modern fastenings to use—a featured standard fastening or a part especially designed to suit your needs.

The part shown above is one of Scovill's many special purpose cold-forged items. Our special processing of this part meant substantial savings in money—materials—motions. Call our Fastenings Expert for assistance so that you likewise may profit. Call him **now.**

SCOVILL MANUFACTURING COMPANY

WATERVILLE SCREW PRODUCTS DIVISION

WATERVILLE 48, CONN. TEL. WATERBURY 3-3151

NEW YORK, Chrysler Building . DETROIT, 714 Fisher Building . CHICAGO, 1229 W. Washington Boulevard . PHILADELPHIA, 18 W. Chelten Avenue Building
PITTSBURGH, 2882 W. Liberty Ave. . SYRACUSE, Syracuse-Kemper Insurance Bldg. . LOS ANGELES, 2827 S. Soto St. . SAN FRANCISCO, 434 Brannan St.

HARDWICK, HINDLE

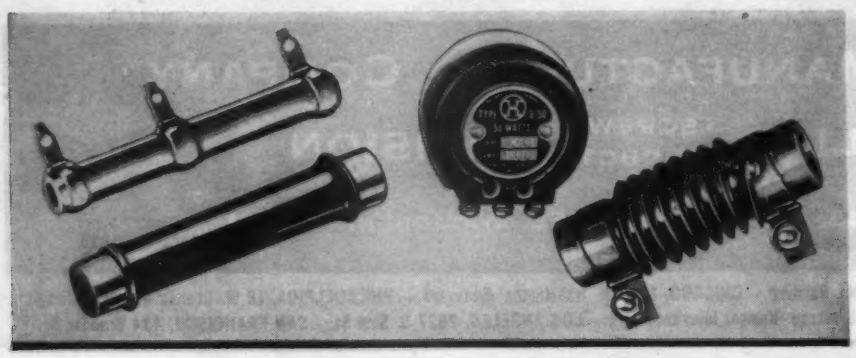
STILL LEADING THE FIELD

Our Blue Ribbon Resistors were unique in their entirely new design and their advanced engineering when we introduced them in 1939.

They still lead the field as the most efficient:—their compactness, their toughness, and their remarkable performance offer you more than just higher wattage ratings for unit space required.

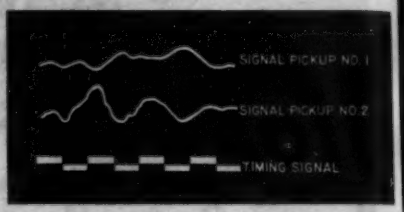
—And in our other types of resistors and rheostats we also offer you important exclusive advantages.

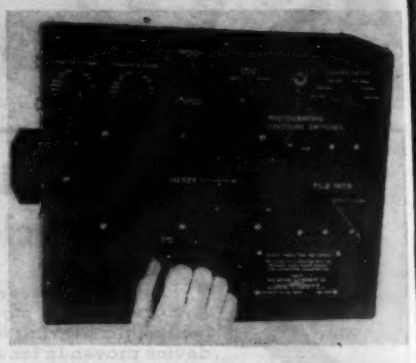
HARDWICK, HINDLE, INC.
RHEOSTATS and RESISTORS
DIVISION OF
THE NATIONAL LOCK WASHER CO.
ESTABLISHED 1886
Newark 5, N. J., U. S. A.



ometer type pickups can be placed at many places about the plane and two of these can be operated simultaneously. A selector switch permits many points to be studied in the same flight. The recorder contains its own batteries, amplifier, electronic switch, and cathode-ray tube as well as a camera to photograph the oscillograph record.

For exhaustive flutter study, equipment weighing between 300 and 500 pounds previously has been used. Installation and tests by this method required about two weeks. Frequently, after the equipment





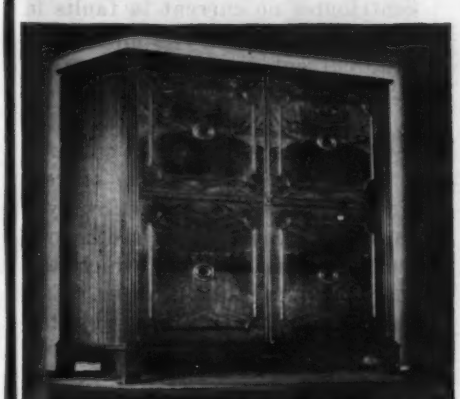
Panel view of the portable flight recorder and a typical photograph of the vibration encountered by pickups located at two positions of stress in the plane

was removed, additional information was needed during analysis of the observations, and the new recorder is ideal for such re-examination. Light enough to be held on the lap of the observer, it can be installed and put into use in a few hours. The machine is also useful in studying vibration in motor mounts, cowling and small accessories, where its ease of installation as a special-purpose instrument is important.

Present knowledge of flutter has been built up over years, and has been gathered from experiments on the ground and in flight. Vibrating machines are still used to simulate flight conditions on the ground. In a few cases, radio-controlled planes have been used with recordings transmitted to the ground during

DOUBLE WINNERS

STROMBERG-CARLSON'S WARTIME ADVERTISING— AND STROMBERG-CARLSON'S POSTWAR RADIOS!



Stromberg-Carlson, Rochester 3, New York
Radios, Television, Telephones, and Sound Equipment

What wartime radio advertising can show such a record of dealer approval—and of public readership—as the current Stromberg-Carlson pages in the national magazines? *None*—the Daniel Starch advertising check-ups have proved that, *plenty!*

And the postwar Stromberg-Carlson FM and AM radios, radio-phonographs, and television sets will be equally far out in front. Tailor-made to the postwar market—as established by our recent 5,000-radio home market survey—they will give the public exactly what it's looking for.

This 5,000-radio home survey brings home clear as a bell the buyers' tremendous insistence on top quality in radio equipment. They expect and will seek out the very best...and back up their insistence with plenty of cold cash.

The distribution of your radio sales promises some important changes, too. Changes in the ratios between radios and radio phonographs, between consoles and table models. Changes and improvements which people want, and which will be reflected in all postwar Stromberg-Carlson equipment . . . a pretty pleasant prospect for every Stromberg-Carlson dealer!

HERE'S THE STROMBERG-CARLSON POSTWAR SET-UP IN 21 SECONDS READING TIME!

1 We will have—soon after Victory—a fine line of Stromberg-Carlson FM and AM radios, phonograph combinations, and television receivers in a wide range of prices.

2 We will have a policy of distribution planned to give every Authorized Dealer a good profit opportunity on the Stromberg-Carlson line.

3 And the Stromberg-Carlson name will be even more widely and more favorably known than ever before.

Now Available
For Prompt Delivery
LINGO
VERTICAL TUBULAR STEEL RADIATORS
are now back in production and can be supplied promptly, subject to existing regulations.
Now, after two years of producing thousands of tubular towers for the Armed Forces, Lingo is again ready to serve the Broadcasting Industry. From the earliest days of "wireless" to the threshold of a new era in broadcasting, Lingo has been constructing and erecting vertical structures that have been setting outstanding efficiency and performance records. Vertical tubular radiators are available in standardized heights from 100 to 500 feet. Lingo also produces tubular steel supporting poles for the accommodation of FM, Television and other UHF antennas.
Our staff will be pleased to provide you with the complete story as it applies in your own case. In writing, please give location, power, frequency of station, and indicate radiator height desired.
JOHN E. LINGO & SON, INC.
EST. 1897 CAMDEN, NEW JERSEY
LINGO VERTICAL TUBULAR STEEL RADIATORS

flight, and test pilots have flown planes equipped with recorders which transmit their reports by radio to the ground. For all of these methods, the new recorder is a valuable auxiliary.

Development of the new recorder was made by the CAA in cooperation with Brown Instrument Company.

• • •

10,000-kw Electronic Converters in Steel Plant

AN ELECTRONIC POWER converter designed to exchange power, reversibly, between 25-cycle, 44-kv and 60-cycle, 69-kv systems has been installed as two complete 10,000-kw units at a plant of Carnegie-Illinois Steel Co. The arrangement permits operation at 125 percent load for one hour and 200 percent load for one minute.

Twelve tubes form the rectifying element for converting 10,000-kw a.c. to d.c. and twelve additional tubes convert the d.c. back to a.c. The direct-current link operates at approximately 30,000 volts. When changing from rectifier to inverter operation for reverse power flow, the phase position of the grid voltage is shifted by a phase-shift network approximately 150 deg.

In operation, the electronic converter is held to a constant power output independently of relative system frequencies and voltages. It contributes no current to faults in the supply system, little more than load current to receiving system faults, while controls suppress power flow to internal faults. Switching is resorted to only for persistent faults. Reactive overexcited current is supplied by synchronous apparatus of both systems, excess losses of which are chargeable to the converter. Efficiencies remain high throughout the load range.

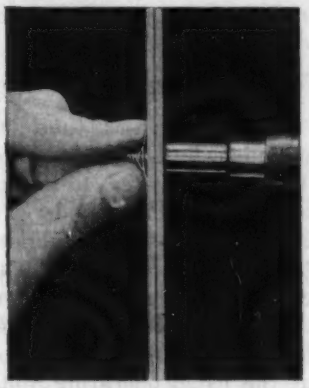
Suppression of Faults

As a result of practical experience with electronic converter systems in the operation of a direct-current power transmission, it has been learned that the electronic converter is subject to occasional faults such as arc backs which apparently cannot be entirely avoided. However, the practical effect of electronic faults can be suppressed so that they do not interfere with

ONE OF A SERIES PORTRAYING THE "SPEED NUT FAMILY OF FASTENINGS"

"...AND WE DO MEAN Speed!"

STARTING POSITION



LOCKING POSITION

Greater *Speed* Reduces Assembly Time
Greater *Speed* Cuts Assembly Costs

● This ad is devoted to speed. The word appears 5 times in this message because we want to stress speed first and foremost.

Why? Because you will need better and faster assembly speed in order to win postwar markets in big volume on any product—metal, wood, or plastics.

Designing beautiful postwar products is only the beginning. The winners will be those good looking products that are engineered for better and faster assembly. We have already produced over 2,000 shapes and sizes that have drastically cut assembly time, reduced costs and improved the quality of the finished product. Write for literature.

TINNERMAN PRODUCTS, INC.
2106 Fulton Road, Cleveland 13, Ohio
In Canada: Wallace Barnes Co., Ltd., Hamilton, Ontario
In England: Simmonds Aerocessories, Ltd., London

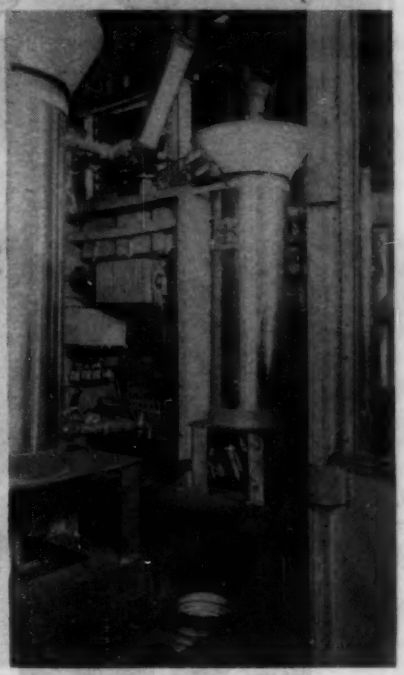
*Speed Nuts** Patented

*Trademark Reg. U. S. Patent Office

FASTEST THING IN FASTENINGS

operation but can be detected by sensitive instruments. The means developed to suppress electronic faults have incidentally introduced the ability to suppress the effects of lightning so that the direct-current power transmission has a remarkably good record for reliability during lightning storms.

Four pentode ignitron groups of 6 tubes each make up a converting equipment. The pentode tube, especially developed for rectifier and converter service, is an ignitron of the permanently evacuated, sealed steel type having the control characteristics of a thyratron tube. One or more grids control the starting of current conduction, aid in deionization at the end of conduction, and reduce the time required to regain control.



A portion of the electronic power converter unit at Carnegie-Illinois Steel Corp. The large cylinders are pentode-ignitron inverter-rectifier tubes. Grid control equipment is in the background

Tube Data

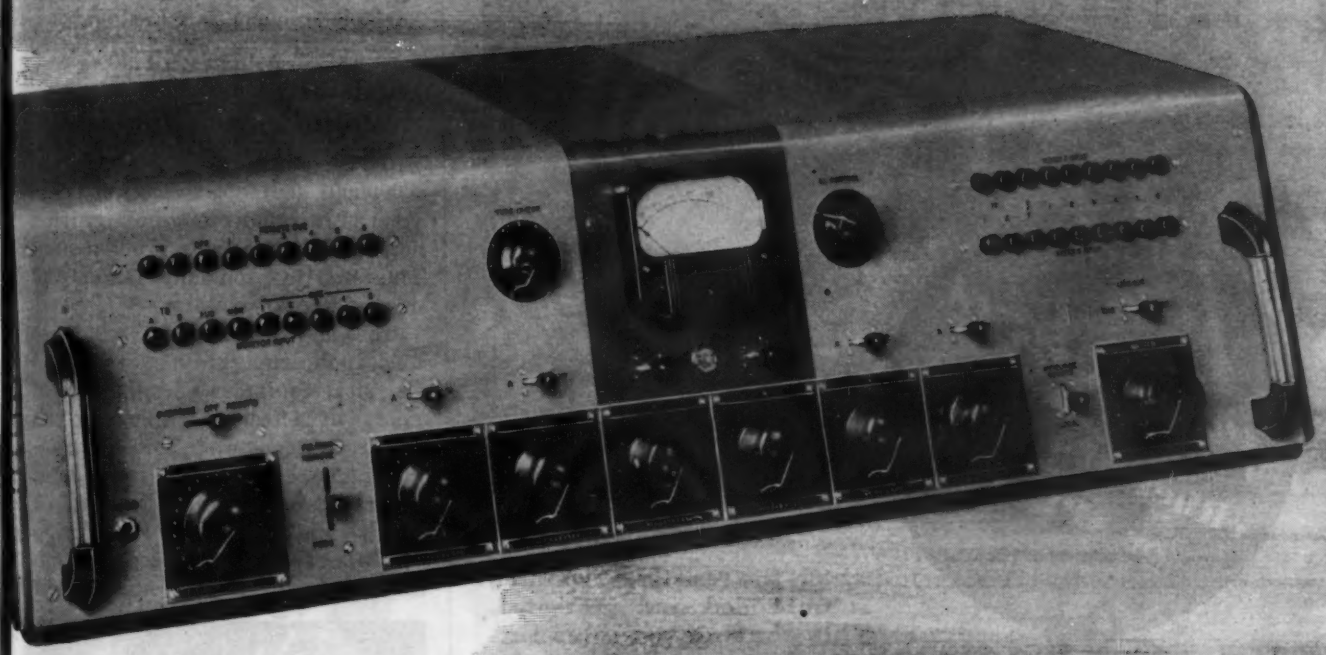
Physically, the tube is of a cylindrical shape approximately 10 in. in diameter, 45 in. in length, and weighs 100 pounds. Two concentric stainless steel cylinders form the enclosing envelope. Water circulates in the space between the cylinders to remove the losses. Tube losses are a fraction of one percent at the usual operating voltage.

Development, design, operating

DEPENDABLE
Dependability, long life and accuracy must be built into transformers from the drafting board to final rigid testing.
Our large engineering staff, constant material control, modern manufacturing equipment and careful testing are your insurance of Dependable
CHICAGO TRANSFORMER
DIVISION OF ESSEX WIRE CORPORATION
3501 WEST ADDISON STREET
CHICAGO, 18

TELL US....

"That 76-B2 is a honey!"



COMPACT... Console measures 39" wide, 17" deep and 10½" high.

COMPLETE... Answers every speech input need of the small and medium-sized broadcast station.

ECONOMICAL... At a price the smallest station can afford.

Perhaps your station lacks the efficient service of an RCA 76-B2 Speech Input System. For further information on its advantages and availability, please address the Broadcast Equipment Section of RCA at Camden, N. J. (Interested in reserving a postwar AM, FM or Television Transmitter? The RCA Broadcast Equipment Priority Plan will interest you. Write today for details.)

1919
1944

RCA

25 Years of Progress In Radio and Electronics

RADIO CORPORATION OF AMERICA

RCA VICTOR DIVISION · CAMDEN, N. J.

In Canada
RCA VICTOR COMPANY LIMITED, MONTREAL

War Bonds... Your Best Investment

Crystal and Dynamic

MICROPHONES

PHONOGRAPH PICKUP ARMS CARTRIDGES and RECORDING HEADS

Known for efficiency, quality and durability. Available with proper priority ratings.

Manufacturing radio cable connectors, antennas, and special sound detection devices for wartime equipment

THE Astatic CORPORATION
ASTATIC
CONNEAUT, OHIO
IN CANADA: CANADIAN ASTATIC LTD., TORONTO, ONTARIO

more data about the ignition systems of high-powered airplane engines than has ever existed before takes pictures on camera film in much the same manner as an x-ray.

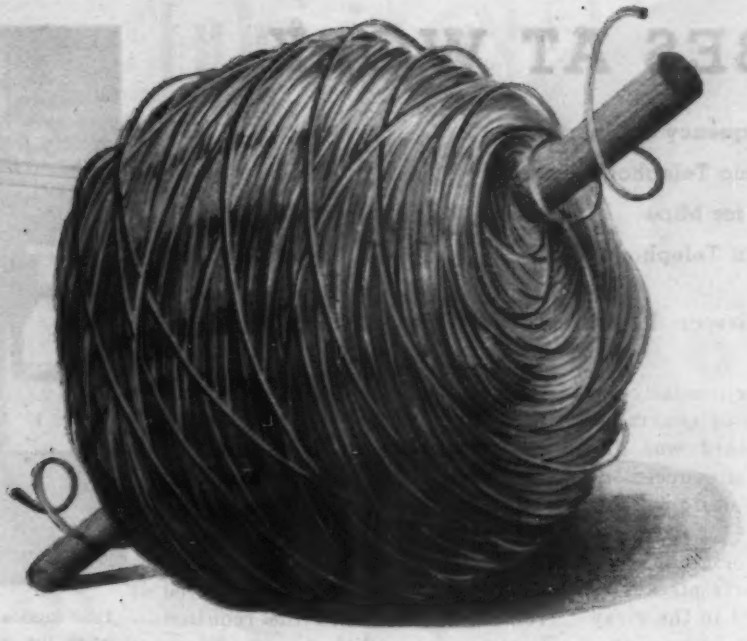
To prevent the beam from registering on the film before the ignition study is made, the unit incorporates a beam trap that deflects the electrons out of the photographic channel. Periods as short as 0.00000001 of a second are photographed on a stationary film strip. Slower speeds, less than 0.000008 second, are recorded on a revolving drum that turns 7,000 times a minute. The rotating film drum is necessary for certain uses because stationary film does not register intervals of 0.02 second.

Westinghouse research engineers collaborated with warplane engine manufacturers in testing ignition systems with the oscillograph and the results pointed the way to better engines by making ignition improvements.

• • •

AMERICAN MINE DETECTOR

Now operating in Europe, this mine detector made by International Detrola Corp. contains three coils in the search head. Two of these are connected in series opposition so that the combined mutual inductance to the third coil is nearly zero. Complete balance is provided by tuned compensator coils in the control box on the handle. Any metallic mass in the coils' field changes the mutual inductance, affecting a meter and an earpiece to provide both audible and visual indication



A Coil is more than just a bundle of wire

ANACONDA COIL ENGINEERS have designed over 15,000 individual types of coils during their many years of experience. Some have weighed as little as 1/100th of a pound; others as much as a quarter of a ton.

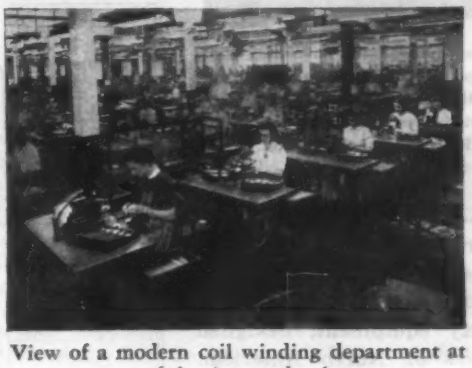
But each coil began with a blueprint. Type, shape, size, winding, insulation, treatment, cost—every factor entering into designing the best coil for the use intended was pre-determined by Anaconda engineers.

Anaconda Coils derive dependability from still another advantage. The magnet wire used for winding them is also a product of Anaconda engineering—with quality carefully controlled from ore to finished wire.

It is a highly effective combination: Coil producers who can command the complete experience of magnet wire specialists! Magnet wire producers who enjoy the close cooperation of coil experts!

And back of each are exceptional manufacturing facilities. Modern plants . . . efficient equipment likewise engineered . . . experienced, skilled personnel.

Any Anaconda sales office will be glad to refer inquiries on coils or magnet wire to our engineeering staff.



View of a modern coil winding department at one of the Anaconda plants.

Magnet wire and coils

ANACONDA

ANACONDA WIRE & CABLE COMPANY

GENERAL OFFICES: 25 Broadway, New York 4 — *Subsidiary of Anaconda Copper Mining Company*

CHICAGO OFFICE: 20 North Wacker Drive 6 • Sales Offices in Principal Cities

TUBES AT WORK

X-Rays Lower Frequency of Quartz Plate 166
A Private Electronic Telephone System 166
Production Tester for Mica 176
Tester for Invasion Telephone Wire 188

X-Rays Lower Frequency of Quartz Plate

A NEW TECHNIQUE for precisely adjusting the frequency of quartz oscillator plates downward was disclosed recently by the announcement of x-ray equipment designed for this application.

Depending on the original characteristics of the quartz plate, frequency may be lowered in the x-ray unit at a rate of 30 to 50 cps per minute. Plates in the 6-8 megacycle range can be changed from 2 to 3

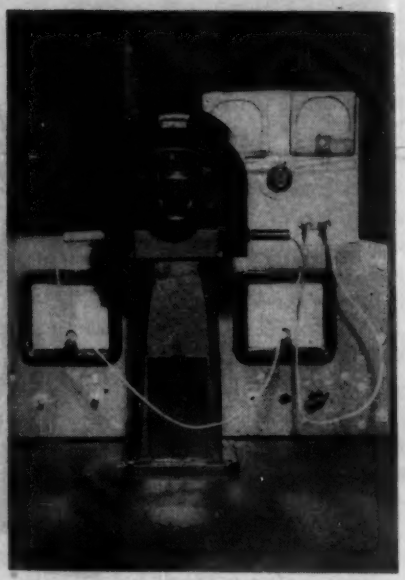
Complete equipment for lowering the frequency of quartz oscillator plates by subjecting the quartz to an x-ray beam. The irradiator was developed by North American Philips in cooperation with the Signal Corps

kilocycles lower in frequency. This is the saturation value of such crystals. Plates of higher frequency can be changed over a larger range.

The x-ray equipment, designed by engineers of North American Philips Co., employs a new high-capacity water-cooled tube that produces an intense beam of x-rays. Intercepting this beam is the crystal holder shown in the photograph, which accommodates two crystals from 0.4 to 0.75 in. in size. One is rotated into the path of the x-ray beam while the other is being loaded. Two crystal holders are provided, one for each window of the x-ray tube.

Leads to the holder in front of the x-ray window may be connected to an oscillator for frequency checking. Thus the degree of downward drift of frequency can be readily monitored and the crystal removed from the beam when the required change is accomplished.

The x-ray equipment for irradiating crystals was developed at the request of the U. S. Army Signal Corps. Experiments made by Dr. Frondel of Reeves Sound Laboratories show that the change in frequency is permanent throughout and beyond any temperature range that the crystal is apt to experience. Factory applications of the technique include: recovery of overshot crystals that have been carried too far in finishing; precise adjustment of standard crystals for use in calibration and in testing; manufacture of precision crystals for frequency and time standards;



This double crystal holder rotates to carry the quartz plate into the x-ray beam while another plate is being loaded aboard. Action of the Norelco x-ray unit lowers the frequency

for a crystal which is considered stable, precise adjustment to final frequency by this method without the possibility of further aging.

A Private Electronic Telephone System

PAUL F. MAGEE
Cross Roads Auto Service
Berlin, Md.

THE BUILDINGS OF this company are spread over about a city block, with a main highway separating the various buildings into two groups. To

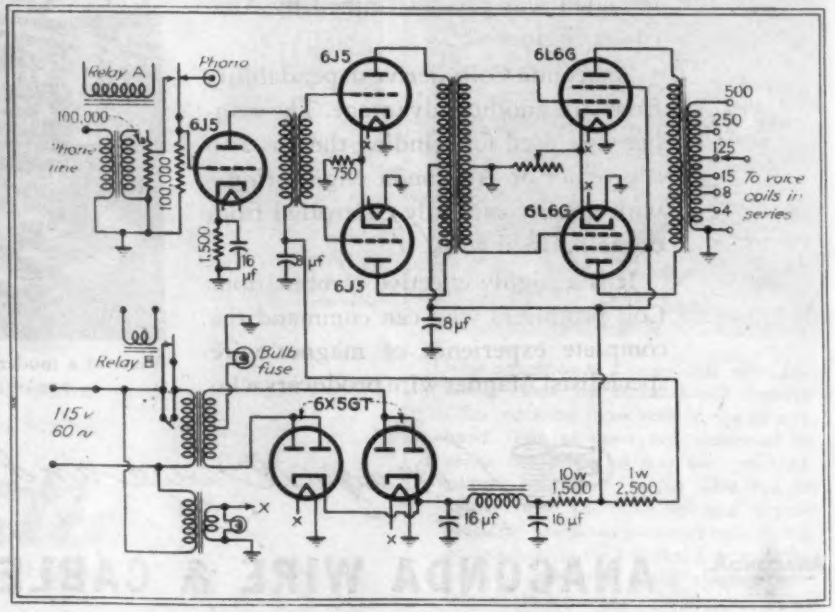


Fig. 1—Complete circuit of amplifier used in the electronic telephone system. The two relays are controlled by a pushbutton at each position

wherever a tube is used

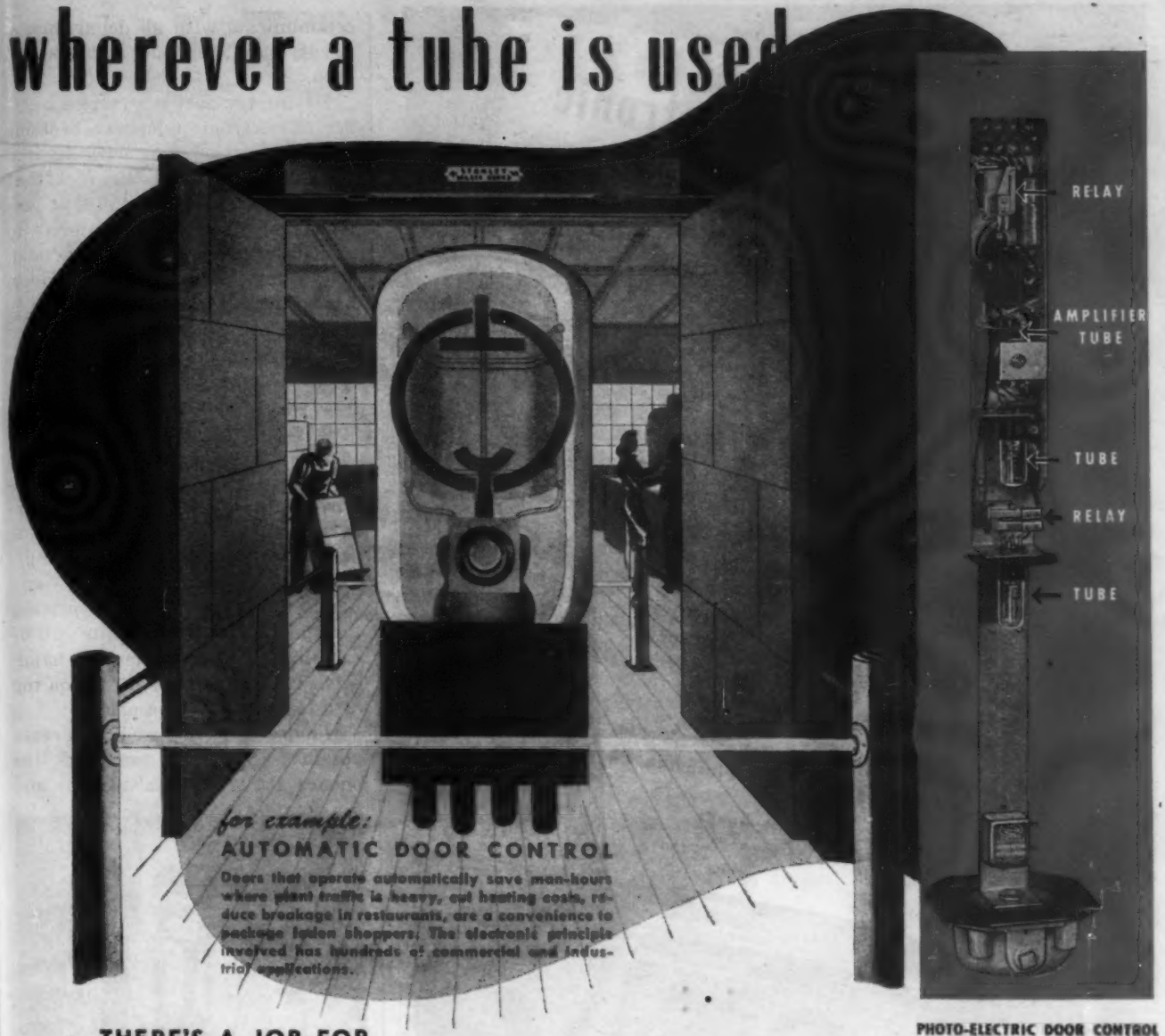

RELAY
AMPLIFIER TUBE
TUBE
RELAY
TUBE
for example:
AUTOMATIC DOOR CONTROL
Doors that operate automatically save man-hours where plant traffic is heavy, cut heating costs, reduce breakage in restaurants, are a convenience to package laden shoppers. The electronic principle involved has hundreds of commercial and industrial applications.

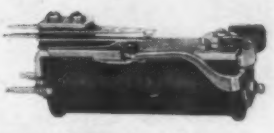
PHOTO-ELECTRIC DOOR CONTROL
Above unit manufactured by General Electric Co., is a part of STANLEY "MAGIC DOOR" CONTROLS.

THERE'S A JOB FOR *Relays* BY GUARDIAN

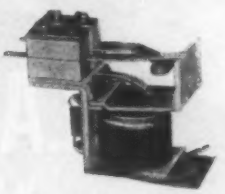
★ **The "Magic Door" made by The Stanley Works of New Britain, Conn., uses a General Electric control unit which operates automatically at the approach of a pedestrian or vehicle. In this unit a beam of light focused on the cathode of a phototube causes a tiny current to flow. Enlarged through an amplifier tube this current operates a sensitive telephone type of relay such as the Guardian Series 405. Another phototube with an auxiliary relay, Guardian Series R-100, is employed to hold the doors open for anyone standing within the doorway.**

The telephone type of relay is extremely sensitive and able to operate on the small current supplied through the electronic circuit. The auxiliary relay, Series R-100, is required to handle a greater current. It is a small, efficient relay having a contact capacity up to 1 KW at frequencies up to and including 28 megacycles. Contact combinations range up to double pole, double throw. Standard coils operate on 110 volts, 60 cycles, and draw approximately 7 V. A. Coils for other voltages are available. For further information write for Bulletin R-6.

Consult Guardian whenever a tube is used—*however*—Relays by Guardian are NOT limited to tube applications but are used wherever automatic control is desired for making, breaking, or changing the characteristics of electrical circuits.

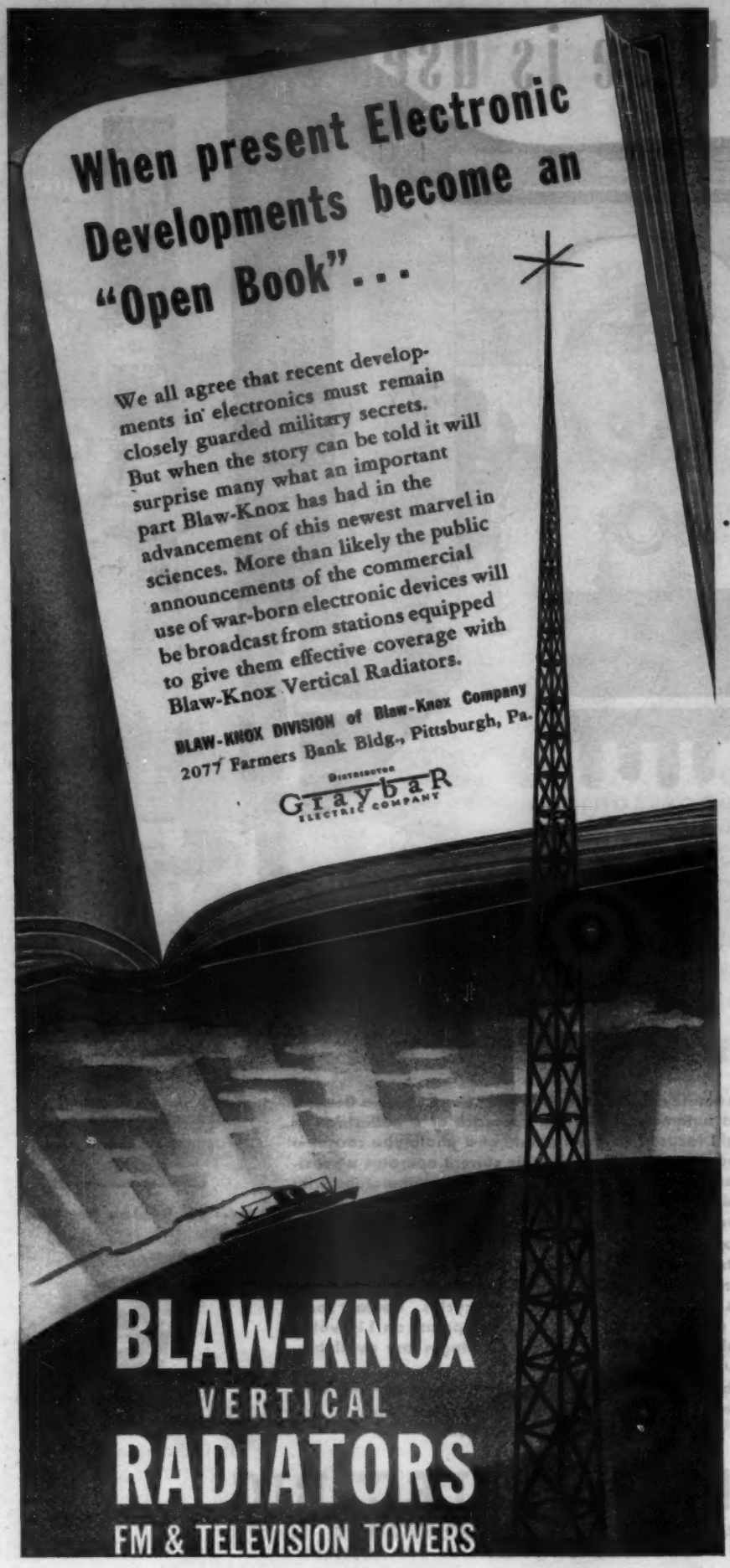


Series 405 Telephone Type Relay



Series R-100 H. F. Relay

GUARDIAN ELECTRIC
1625-M W. WALNUT STREET CHICAGO 12, ILLINOIS
A COMPLETE LINE OF RELAYS SERVING AMERICAN WAR INDUSTRY


When present Electronic Developments become an "Open Book"...
We all agree that recent developments in electronics must remain closely guarded military secrets. But when the story can be told it will surprise many what an important part Blaw-Knox has had in the advancement of this newest marvel in sciences. More than likely the public announcements of the commercial use of war-born electronic devices will be broadcast from stations equipped to give them effective coverage with Blaw-Knox Vertical Radiators.
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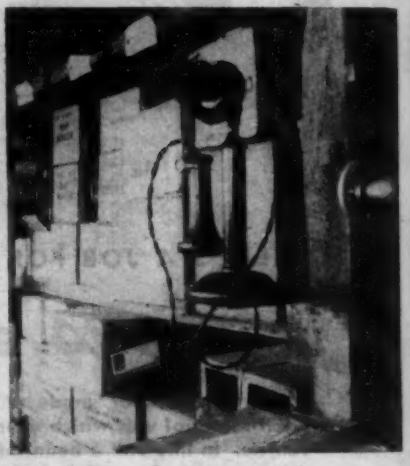
communicate with all departments, twenty-one telephone stations are used.

During the past ten years a number of electronic telephone systems have been tried, but with limited success, due mainly to the fact, that after a system was installed it was too complicated for the majority to use, or was not entirely practical. The system diagrammed, however, has proven satisfactory for over three years.

The system is designed for ease of operation. Pushbuttons on each handset permit calling over all speakers at one time. After the initial call is made, consisting usually of one or two words, the pushbutton is released and conversation is carried on by means of handsets located in all the buildings. Feedback between speakers and handsets is eliminated by placing the speakers at the opposite end of each building away from the handsets. The amplifier is located on top of a large safe in the office.

Handsets were used wherever possible, however, some of the phones are from a salvage lot and



One of the telephone installations in a stock-room. Not shown in the photo, a loudspeaker is used for paging employees and then cut off during the phone conversation

are the vertical type with receiver hanging on a hook on the side. These are mounted by means of an L-shaped piece of steel to the building wherever used. In the beginning, several of the "toy" type phones were installed, but these were none too successful.

Relay-Controlled Amplifier

A jack is provided in the amplifier for "phono" use for keeping the

Sangamo Capacitors Can Take It!
Mica capacitors play a vital part in the correct functioning of many types of equipment. Radio receivers, transmitters, hearing aids, underwater sound equipment, induction heating, and many other devices depend upon the faithful performance of capacitors to enable them to function properly.
Many applications of capacitors in these various equipments necessitate a wide range of sizes, shapes, voltages, and current carrying ability in order that the proper capacitor may be used, depending upon the physical space limitations and electrical characteristics to be met.
As illustrated, Sangamo manufactures a large variety of capacitors from the small wire lead type having a body size of only 23/32" in length, 15/32" in width, and .20" thick to the large ceramic case type capable of operating at voltages up to 35,000 and handling large amounts of radio frequency current. This wide variety of capacitors insures the availability of the proper unit for almost any mica capacitor requirement.
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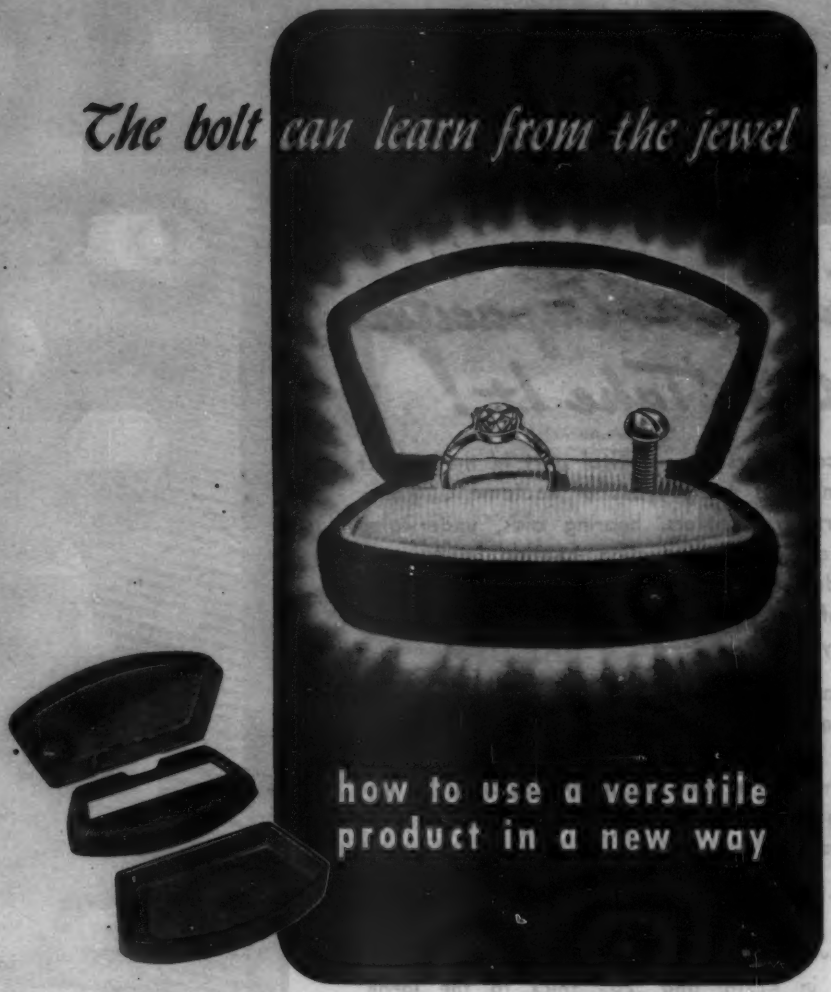

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- ☐ **SAMPLES OF FABRICATED PARTS, some of which are shown at right. Extensive tool and die facilities are available.**
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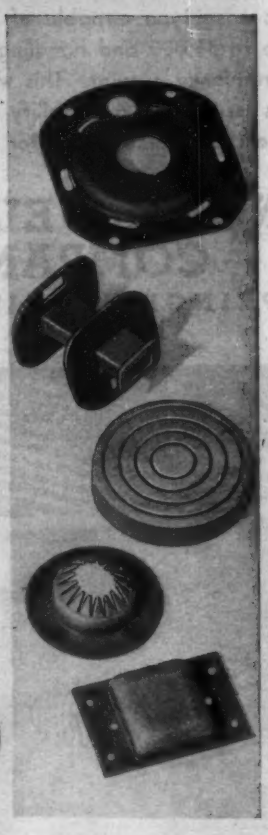

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amplifier on at all times. Two 6-volt d-c relays are controlled by the pushbuttons. Relay *A* switches the amplifier into the telephone circuit without the phono in use, and relay *B* applies the line voltage to the primary of the high-voltage transformer. A battery of 12 volts was necessary to operate the two 6-volt relays as they are connected in series, but they operate without fail from the pushbutton switch most distant from the amplifier.

The microphone input transformer permits matching from a 50–100–150–200 ohm source to the grid of the tube. The 50-ohm tap is used, as there are always at least two phones in the circuit at one time, and at many times several. There seems to be no difference in the level of conversation.

Use of the primary winding of the microphone transformer permits the phones to operate. Almost any iron-core choke would work as

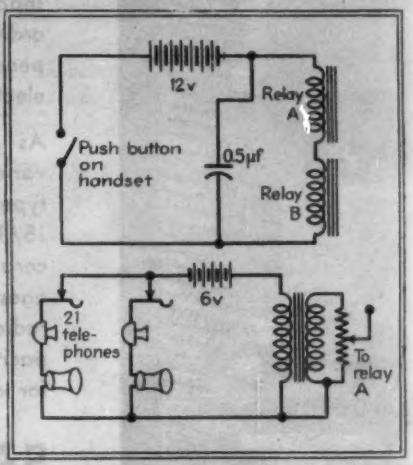


Fig. 2—Battery circuits for operating the relays and telephones

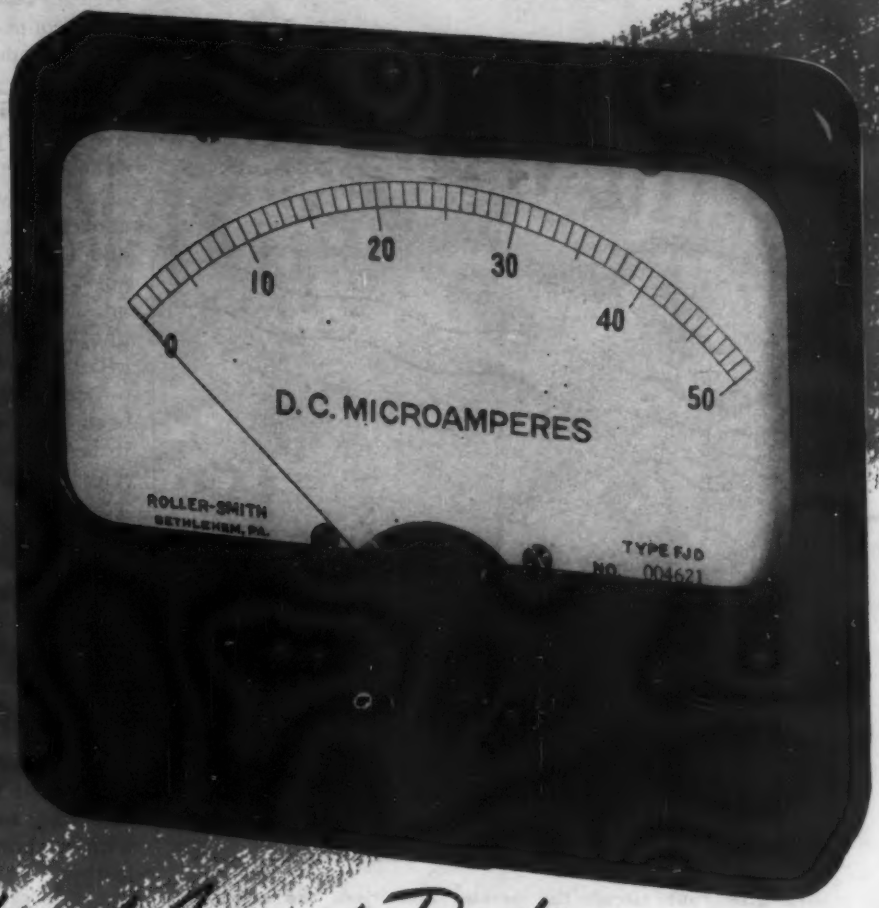
a substitute if telephone conversation alone was all that was required, but since it is also needed for the amplifier, this primary winding serves a dual purpose.

The filament transformer case was bored full of holes for freer circulation of air around the core. It is left on the line continuously to keep moisture out of the amplifier. No trouble has been experienced from burnout.

Two Types of Lines

The wire lines between buildings are run on 25-foot creosoted poles except for one 125-foot section that is underground. This section consists of a lead cable in 4-in. tile. The overhead lines are No. 14 sin-

ROLLER-SMITH 4.5" PANEL INSTRUMENTS...



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Where panel conditions permit their installation these 4.5" semi-flush Bakelite case instruments provide maximum readability. Scale length of d-c instruments is 3⅛ inches and for a-c instruments is 3½ inches. All instruments except rectifier types are accurate within 1% of full scale value at any point on the scale. Rectifier types, approximately 5%.

Incorporating the long life and dependability developed during 40 years of fine instrument manufacture, R-S 4.5" panel instruments have a diversified field of application which includes: Radio Transmitters; Control Panels; Battery Testers and Chargers; Electronic Tube Testers and Analyzers; Automotive Analyzers: Instrument Test Units; Sound Movie Equipment; Motion Picture Control Panels: Arc Welding Equipment; Experimental and Amateur Radio; General Electrical Laboratory Testing; General Communications, etc.

Any practical range can be supplied on short notice in d-c and a-c (Repulsion iron-vane and Rectifier type) models, with single or multi-range scales. Correspondence is invited.

OTHER R-S INSTRUMENTS: *Panel, switchboard and portable instruments of practically every standard size, shape, capacity, type and style are included in the R-S line of electrical instruments. Shown here are (upper) 3.5" Miniature Panel Ammeter conforming to American War Standard C39. 2-1944 and (lower) "Steel-Six" Portable Ammeter.*

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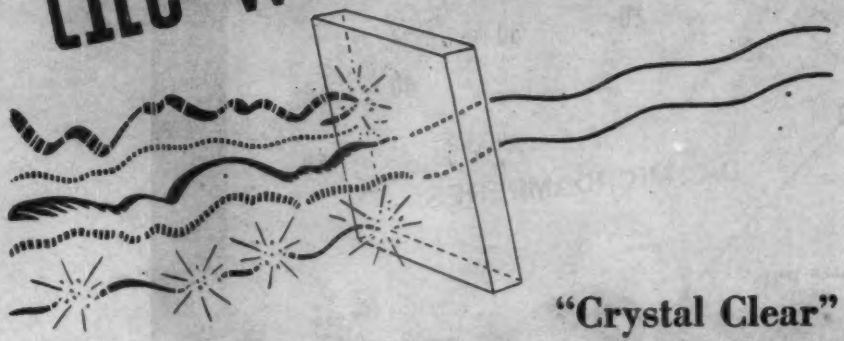

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radio reception is a fundamental of the public's expectation postwar. It is the very cornerstone of broadcast receiver sales. There can no longer be any doubt about it.

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gle-strand wire spaced about 6 to 10 inches apart. Colored wires were used for coding the six wires needed.

In connecting the overhead line to the underground line, a special transformer was found necessary. A transformer of the type used to match the plate of a vacuum tube to a 500-ohm line was found suitable. Without the transformer, the capacitance of the line was 0.01 μf and speech signals were considerably distorted. There seemed to be no noticeable difference when the line was connected or disconnected after the transformer was installed.

Total length of the lines has not been measured, but it is estimated to be ¼ mile. There are no ground connections to the various lines anywhere except at the amplifier and this is tied to a 1¼-inch water main.

Each station is set up with two-wire terminal blocks. The lines are wired to one side of the blocks and the phones, pushbuttons and speakers wired to the other side. This facilitates quick change of units without disturbing the lines. All joints in the lines were soldered.

Since the voice coils are connected in series, each speaker is supplied with a short-circuiting switch for testing. So far, none of the voice coils has failed. Resistance may be inserted in series with the speaker line to compensate for mismatch with the output transformer.

Additions to the installation were made gradually over a period of two years and no improvements have been made recently.

• • •

Production Tester for Mica

THE BEST RUBY MUSCOVITE mica has come from India, but there are large deposits of ruby and other types of muscovite mica in the United States, South America, and Canada. If these were available for mica capacitors, not only would the supply be greatly increased, but the transportation difficulties would be lessened.

Because of this situation, the War Production Board appealed to Bell Laboratories in the fall of 1942 to devise a method of testing and classifying mica that would give more positive results and insure that no good mica of any type was rejected. What was urgently needed was a quick and easy method of detecting conducting regions, and for

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We will gladly furnish complete information on these and other advantages of the HG-5-KW and HG-50-KW Transmitters, such as: *Low Operating Cost, High Fidelity Signals, Continuity of Operation, Simplicity of Control.*

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By placing your order today for a Westinghouse Transmitter, you assure yourself of the fastest possible delivery following the lifting of wartime manufacturing restrictions. We are scheduling deliveries in the sequence in which orders are received. For details, write Westinghouse Electric & Mfg. Company, Dept. 1NB, P. O. Box 868, Pittsburgh 30, Pa.

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IMMEDIATE DELIVERY ON PROPER PRIORITY

This dependable, sensitive indicator meets the need for providing a convenient and accurate means of determining resonance in oscillators and transmitters:

STANDARD WAVE RATIOS	TANK CIRCUITS
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Because it is a rectifier type vacuum tube voltmeter, it is not subject to damage by severe over-loads.

The MW-60 is the result of ERCO'S specialized engineering knowledge and manufacture of custom radio communication equipment.

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LITERATURE ON REQUEST

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Manufacturers of CUSTOM BUILT RADIO APPARATUS

determining the dielectric loss under the influence of the alternating voltages the mica would encounter in service. To meet these needs, the Laboratories undertook an investigation that culminated in the design of two test sets: one to detect conducting regions, and one to measure the dielectric loss of raw mica in "block" form. This term applies to sheet mica ranging from 7 to 30 mils in thickness. The test sets are described by K. G. Coultee in the September, 1944 issue of *Bell Laboratories Record.*

One test set determines loss by measuring the power factor of the current flowing through the mica when high-frequency voltage is applied across it. Since ordinary methods of measuring power factor

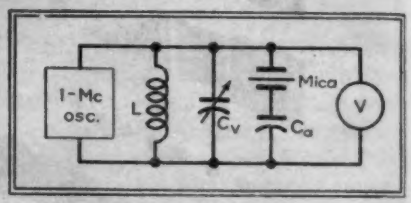

Fig. 1—Simplified circuit illustrating the principle of operation of the tester for measuring the dielectric loss of raw mica

are too slow for a commercial test of this type, a circuit was designed that gave a suitable measure of loss as a single reading of a voltmeter. The principle of the circuit employed is illustrated in Fig. 1.

A high-frequency oscillator is coupled to a circuit consisting of an inductance L, an adjustable capacitor C_v, and a fixed air capacitor C_a of negligible loss. The mica sheet to be tested is placed in series with the air capacitor C_a. A voltmeter across the circuit measures the voltage both before and after the mica is in place. Prior to a series of tests, and before any mica has been inserted in series with C_a, the circuit is tuned to the applied frequency, and the input is adjusted to give full scale reading on the voltmeter.

Operation

When a sample of block mica is now inserted in series with C_a, it detunes the circuit, which is retuned to resonance by adjusting C_v until a maximum reading is obtained on the voltmeter. If there were no loss in the mica, that is, if the power factor were 0, the meter

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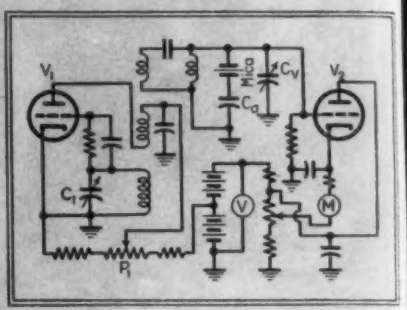
reading would be at full scale as before. Any loss in the mica appears as a series resistance and less current flows causing the voltmeter to indicate less than full scale.

The circuit actually employed is shown in Fig. 2. Tube V_1 is in the oscillator circuit, which is adjusted to a frequency of one megacycle and proper output power by adjusting C_1 and P_1. Tube V_2 forms part of a vacuum-tube voltmeter. Its reading, taken on meter M, is used for classifying the mica in terms of power factor.

On the panel of the tester is a knob used for raising and lowering C_a so that a sheet of mica can be inserted between it and the lower electrode. This dial is also arranged to



indicate the thickness of the sample of mica under test. For each test, the sheet of mica is placed between C_a and the lower electrode, and the sheet of mica is placed between C_a and the lower electrode, and the knob is turned to clamp it in place. Capacitor C_v is then adjusted to give a maximum reading on the meter.

It was found possible to correlate the results obtained from the tests with the power factor indication of the test set. As a result of the correlation, three ranges of power factor were established, each lying between certain pointer readings on the test set. These ranges appear as diagonal lines on the scale of the meter. The reading of the test set also varies with the thickness of the mica as shown by the clamping dial, and the scale of the meter is arranged to permit this factor to be taken into consideration. With the unit, it is possible to test as many as fifteen samples of block mica per minute, while with the more conventional methods at least fifteen minutes would be required for each test.

To discover conducting regions in stained mica prior to the power fac-

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Variable air condensers of Radio Condenser Co.—because they provide such *accurate* and *distinct* tuning—should be included in your sets.

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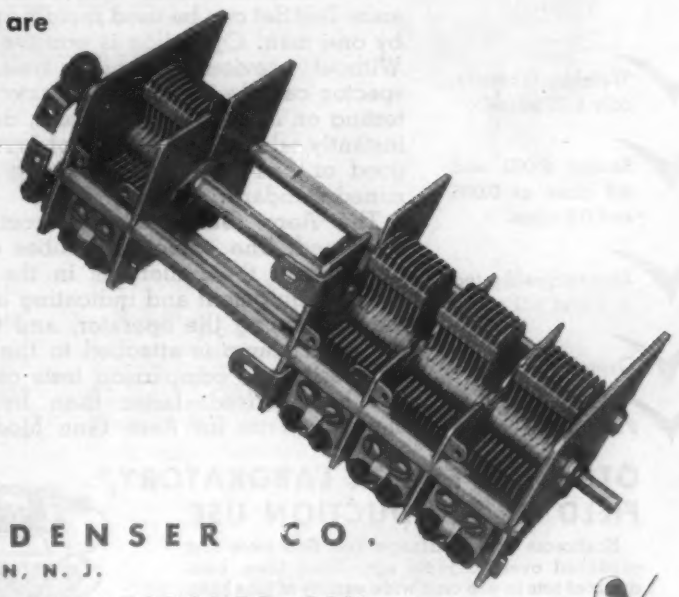

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The Shallcross Aero Gun Model Low-Resistance Test Set can be used rapidly and efficiently by one man. Operation is positive and simple. Without previous technical training, an inspector can do a quick, accurate job of bond testing on a "Go, No-Go" basis, demonstrating instantly whether an electrical bond or joint is good or bad by comparison with a predetermined standard.

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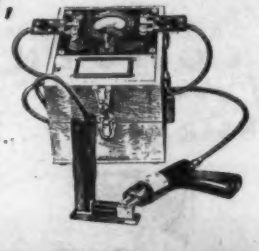
Shallcross Low-Resistance Test Sets were first produced over 10 years ago. Since then, hundreds of sets in use on a wide variety of jobs have proved the outstanding advantages of this method of testing.... The present Shallcross line includes Test Sets for practically every field service, laboratory, or industrial production line requirement. Write for the complete Low-Resistance Test Set Catalog.



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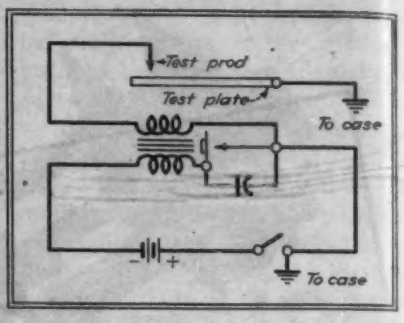


Fig. 3—This spark coil setup shows conducting regions in mica when a sheet of it is placed on the test plate and the test prod moved over the surface

tor test, a battery-operated spark coil was arranged as shown in Fig. 3. A sheet of mica is placed on the test plate and the test point is moved over its surface. Any defective regions are indicated by sparking at or in the vicinity of the point. Only a few seconds are required for each test.

By the use of these two test sets, a large quantity of block muscovite mica, considered unusable for capacitors by the previous methods, was selected and used in about 40,000 capacitors by several manufacturers. These capacitors fully met thorough performance and life tests made by the manufacturers, and proved the reliability of the test set classification. As a result of this commercial trial, an increase of about 50 percent in the muscovite mica suitable for use in capacitors has been realized.

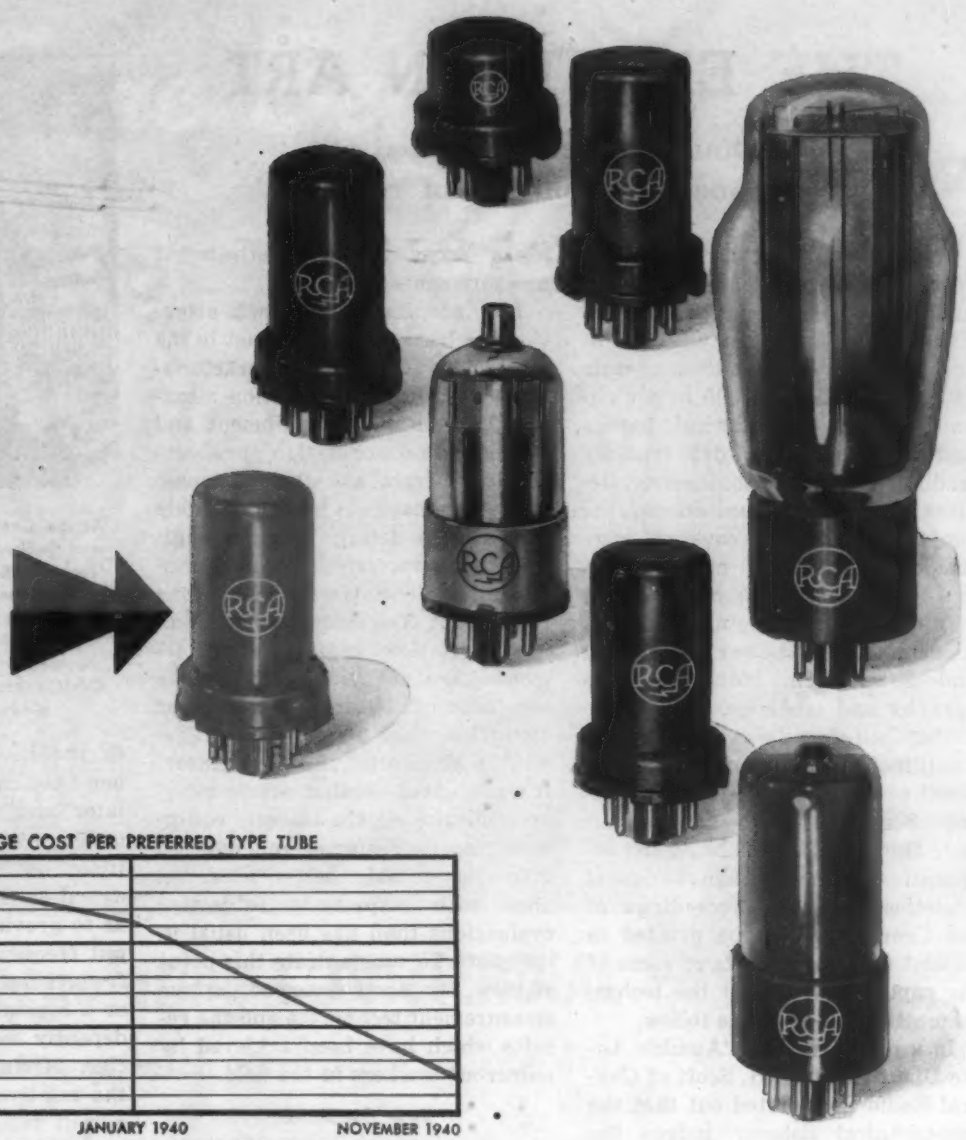
• • •

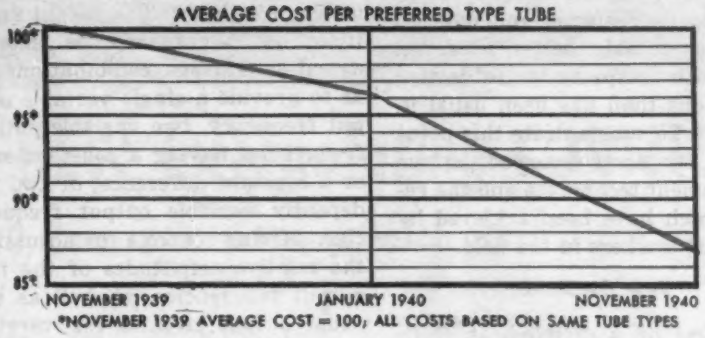
Tester for Invasion Telephone Wire

FIELD TELEPHONE WIRE at a U.S. Army invasion base in southern England is tested for breaks and salvaged for further use by an ingenious device designed by Staff Sergeant Pasqual L. Wamil of Santa Barbara, Calif.

The tester consists of pipes through which the wire passes while being wound onto spools, and a control box with a bell. When a break in the insulation is encountered, a spark jumps between the pipe and the wire and causes the bell to ring. After the original model operated successfully, three additional pipes were added. Drop-out annunciator tabs show which pipe is carrying the defective wire.

THIS ONE'S "ON RCA"





*NOVEMBER 1939 AVERAGE COST = 100; ALL COSTS BASED ON SAME TUBE TYPES

Here's Why— RCA's Preferred-Type Program Slashed Tube Costs to Manufacturers More Than 13% During Its First Year... Giving You One Tube in Eight "On the House" by Former Price Standards

The Preferred-Type Idea makes sense. And, it works!

Introduced by RCA in January, 1940, the Preferred-Type Program aimed at concentrating a larger demand and production on fewer tube types. This would allow greater manufacturing efficiency, because of longer runs, and would mean higher-quality, lower-cost tubes for you.

Even before civilian radio manufacturing was suspended by war, the program paid off. By November, 1940, the average cost to you of tubes on the RCA preferred list was lower by 13% than the average cost of the same tubes in November, 1939 . . . before the program started.

Yet all the time their cost was being lowered, the tubes improved in quality and performance. And the way was being cleared for simplified tube warehousing and stocking.

Since Pearl Harbor, the value of the "preferred-type" idea has been proved beyond a doubt on the world's battlefields. Most military electronic equipment has been designed around an Army/Navy Preferred List of Vacuum Tubes . . . and our fighting men on every continent are assured speedy replacements of high-performance tubes as a result.

Will RCA continue the Preferred-Type Program after the war? You bet it will! If you already have specific tube complements in mind for postwar and would like to know if the tubes you need will be on the preferred list, let us know what they are. Write to Radio Corporation of America, Commercial Engineering Section, Dept. 62-12E, Harrison, New Jersey.

The Magic Brain of all electronic equipment is a Tube . . . and the fountain-head of modern Tube development is RCA.

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THE ELECTRON ART

Technical Papers Delivered at National Electronics Conference

DESIGNED TO SERVE as a national forum on electronic developments and their application, the National Electronics Conference was held at the Medinah Club, Chicago, early in October. To the 2300 in attendance, about 50 technical papers and addresses were delivered by leading electronic engineers. Besides use in communications, the subjects discussed covered electronic applications in measurement and control, high-frequency heating of dielectrics and metals, aviation, industrial uses, power generation and distribution, industrial radiography and medicine.

The Conference was sponsored by the Illinois Institute of Technology, Northwestern University, the Chicago Section of IRE and the Chicago Section of AIEE, with the cooperation of the Chicago Technical Societies Council. Proceedings of the Conference will be printed in booklet form. Abstracts of some of the papers delivered at the technical meetings and forums follow.

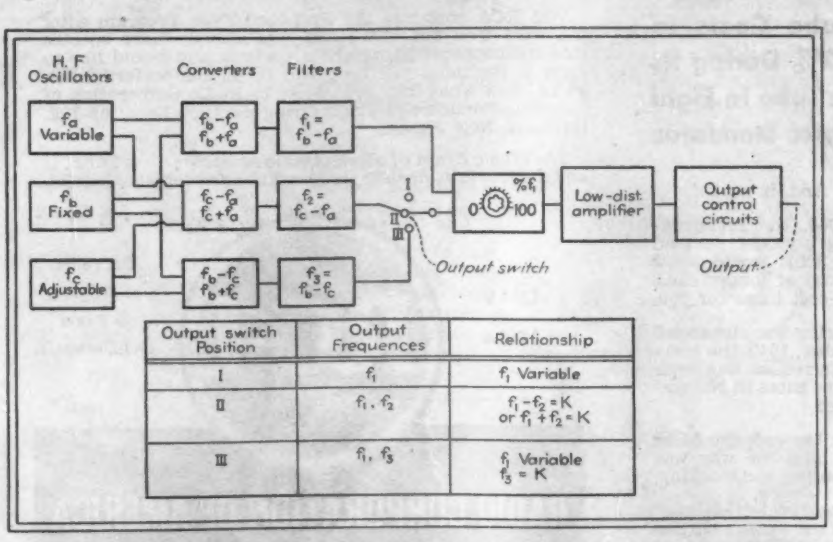
In a paper entitled "Audible Audio Distortion," H. H. Scott of General Radio Co. pointed out that the non-technical listener judges the quality of sound reproduction subjectively and that such listening evaluations do not always agree with the result obtained by engineers from various methods of measurements.

In his opinion, too much attention has been paid in the past to the amplitude-frequency characteristics and harmonic distortion measurements on sound equipment and serious intermodulation products resulting from so-called harmonic distortions have not been adequately evaluated in determining the engineering characteristics of such systems. While moderate deviations from a flat frequency response and small variations in the level of harmonics are not considered by the non-technical listener to represent distortion, they do represent undesirable attributes to the engineer. It was pointed out that within given price limits, electro-acoustic equipment can be designed and built to give considerably better performance with respect to subjective evaluations than has been usual in the past. To substantiate this point of view, Mr. Scott reviewed various measurement techniques and the results which have been achieved by numerous workers in the field.

New Oscillator

The use of a double-beat oscillator for intermodulation measurements was advocated. A block diagram of such an oscillator is shown in the illustration; it consists of one fixed oscillator, a variable oscillator and an adjustable high-frequency oscillator. The output from these oscillators may be heterodyned in various combinations so as to provide a single variable output frequency, two variable output frequencies having a constant sum or a constant difference, or two indepently variable output frequencies. Mixing controls for adjusting the relative amplitudes of the two output frequencies, as well as the usual output circuits for varying the total output over wide ranges, are useful adjustments in the measuring technique. The result of measurements made with such a double-beat oscillator technique were shown.

At the Conference, the speakers' table was flanked by enlarged photos of (left) Joseph R. Redman, chief of Naval Communications, and Major General H. C. Inglis, Chief Signal Officer of the Army. Speeches from the two officers were recorded in Washington on a General Electric magnetic wire recorder and played back at the banquet

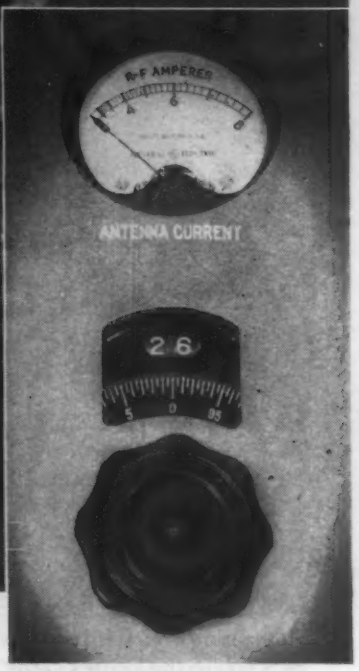


Output switch Position	Output Frequences	Relationship
I	f_1	f_1 Variable
II	f_1, f_2	$f_1 - f_2 = K$ or $f_1 + f_2 = K$
III	f_1, f_3	f_1 Variable $f_3 = K$

Block diagram of a double-beat oscillator arrangement for measurement of intermodulation. The chart shows the various outputs that are provided

G. L. Beers described "A Frequency Dividing Locked-In Oscillator F-M Receiver" in which a continuously operating local oscillator is frequency modulated by the received signal. The frequency of the oscillator is locked-in with the received signal at one-fifth of the intermediate frequency. With this five-to-one relationship between the intermediate frequency and the oscillator frequency, an equivalent reduction in the frequency variations of the local oscillator is obtained.

The locked-in oscillator circuit diagram is shown herewith. The tube generally used in this circuit has been an A-5581, an experi-



The counterdial in an antenna network application

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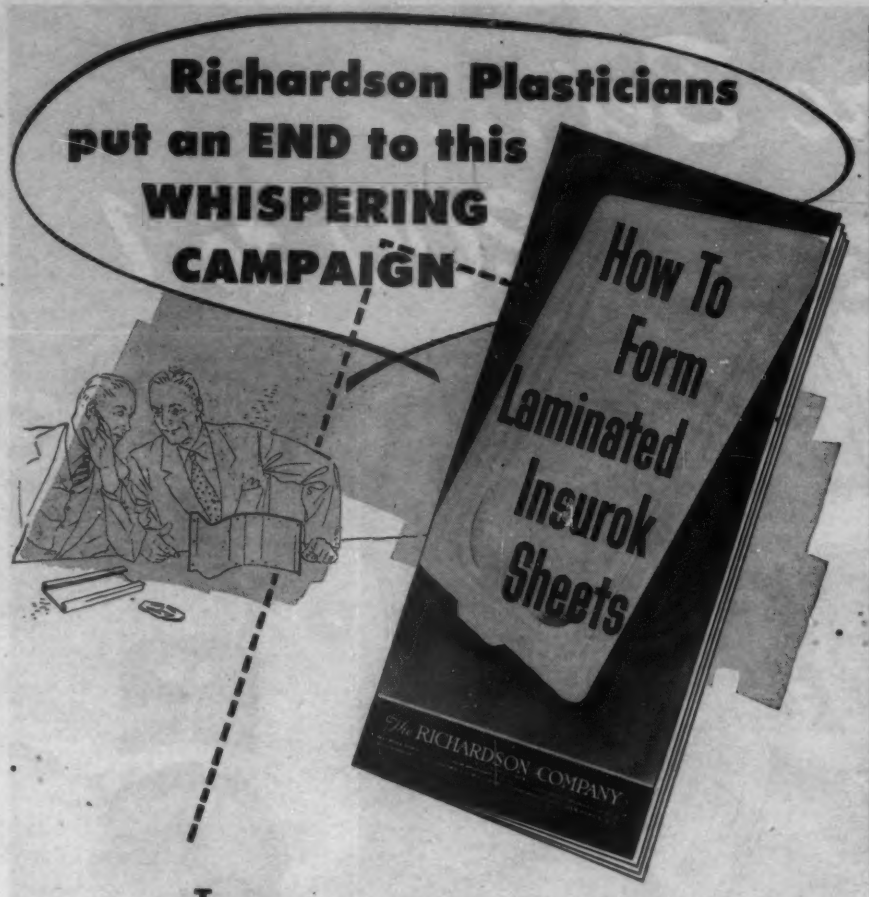

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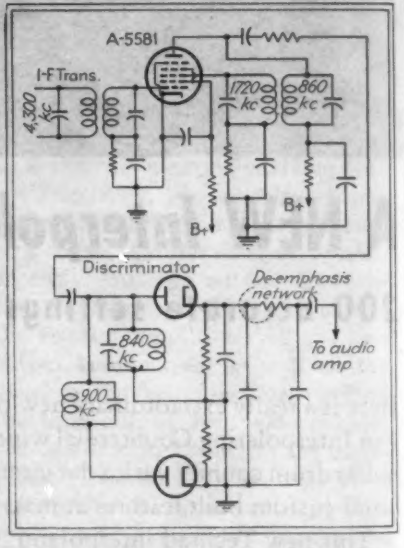
mental converter tube which is similar to the 6SA7 but has a higher transconductance. The oscillator tuned circuit is connected to the plate of the tube and the feedback coil is connected to the No. 3 grid. This grid is operated with self bias. The received signal is applied to the No. 1 grid of the tube from a 4300-kc i-f transformer. The No. 1 grid is likewise operated with self bias.

Discriminator

The output of the local oscillator is fed to the discriminator as shown. This circuit has a pair of diodes connected with the load resistors in opposition so the discriminator is balanced at the center frequency. One diode has a tuned circuit in series with it and the other has a tuned circuit across it. The audio frequency output of the discriminator is fed through a de-emphasis network to the audio amplifier.

The oscillator is designed to lock in only with frequency variations which occur within the desired signal channel and is therefore prevented from following the frequency variations of a signal on an adjacent channel. A substantial improvement in selectivity is thus obtained. The voltage required to lock in the oscillator with a weak signal is approximately 1/20th of the voltage applied to the discriminator. Since this voltage gain is obtained with a different and lower frequency than the intermediate frequency, the stability of the re-



At the top of the diagram is the oscillator which is locked in with the received frequency. Output of the oscillator feeds directly to the discriminator at bottom

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ceiver from the standpoint of overall feedback is materially improved. Not only is adjacent-channel selectivity increased but reduction in noise is also obtained.

Advantages

Theoretical and experimental investigations indicate that the system has the following advantages:

(1) By restricting the locked-in range of the oscillator to follow only the frequency variations which occur within the desired signal channel, a material improvement in selectivity is obtained.

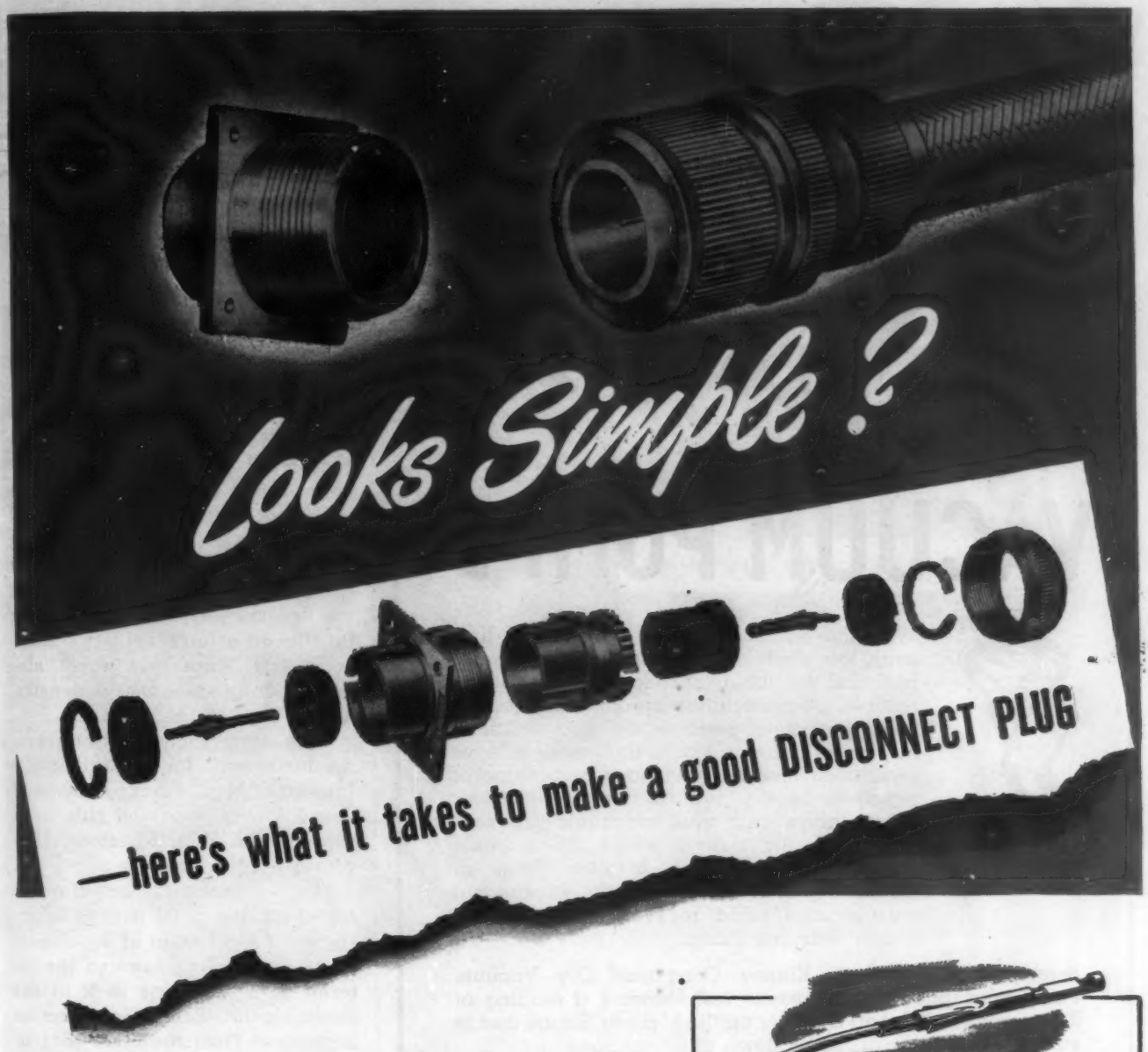
(2) An equivalent voltage stepup is secured at a different and lower frequency than the intermediate frequency and a corresponding improvement in freedom from overall feedback is secured.

(3) The constant voltage is applied to the discriminator irrespective of the strength of a received signal, and arrangement for minimizing amplitude variations in a received signal are therefore not required.

(4) The system provides a means for incorporating in a f-m receiver a type of selectivity which can be used to discriminate between the desired signal modulation and frequency modulation noise component.

The following characteristics should also be considered in evaluating the system: (1) Adequate receiver gain ahead of the locked-in oscillator must be provided if distortion of the weaker signals (due to oscillator falling out of step) is to be prevented. (2) When the receiver is tuned to a signal, more noticeable distortion occurs at the edges of the receiver response characteristic than is obtained with the corresponding conventional receiver.

A paper by Dr. Leon Brillouin of Columbia University and the Federal Telegraph Radio Laboratories of New York emphasized the importance of a well-known theorem originally due to Larmor. This theorem permits a definition of "momentum" and "moment of momentum" for electrons in the magnetic field. As typical examples of application two special cases were discussed: (1) a plane electron beam; (2) a cylindrical electron beam with longitudinal magnetic fields. In



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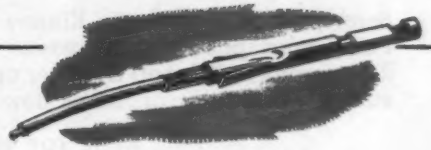
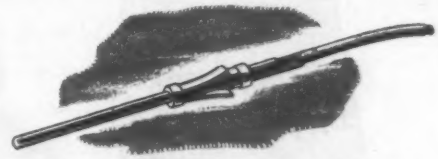
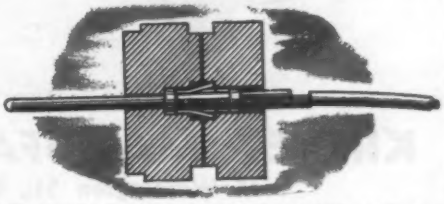


Socket construction features spring-loaded contact for positive electrical connection with pin.



Both pin and socket feature spring snap for ease of assembly in housing insulators after soldering.



Cross-section illustrating how contact pin is snapped into place after soldering on lead wires.

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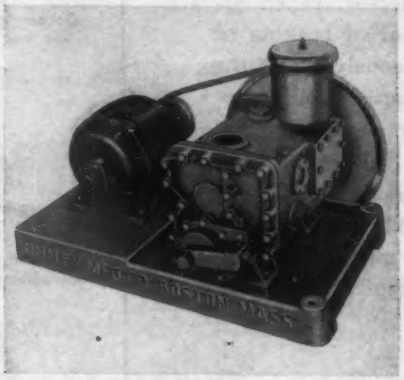

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both cases, it was found that the space charge density of the beam is entirely controlled by the magnetic field, and the maximum current is obtained for a suitable optimum magnetic field.

Space Charge and Magnetic Field

Dr. Brillouin's general conclusion, as the result of a mathematical treatment, is that such problems as Larmor's theorem introduces an additional condition of conservation for either the momentum or the moments of momentum which has been too often overlooked. If taken into account, it shows that the space charge density is entirely conditioned and controlled by the magnetic field. Caution is therefore urged not to introduce in a discussion separate assumptions about space charge and magnetic field. It it especially advised not to speak of the behavior of a device under an infinite or arbitrarily large magnetic field, since this would also mean infinite space charge density, a very troublesome factor.

"The Supersonic Reflectoscope, An Instrument for Inspecting the Interior of Metal Parts by means of Sound Waves" was the title of a paper by Dr. F. A. Firestone, University of Michigan.

The supersonic reflectoscope sends into the metal part to be inspected a short train of supersonic sound waves. Any flaws on the interior give reflections back to the sending point before the reflection is received from the other side of the piece. Many feet of metal can be penetrated.

In addition to the detection of flaws, the thickness of a piece can be measured when its opposite side is inaccessible, and discontinuities of bond of plated or soldered surfaces can be detected.

A paper by Dr. E. U. Condon, of the Westinghouse Research Laboratories, gave an elementary discussion of the way in which the behavior of class C oscillators, intended for use at microwave frequencies, is limited by the speed of electron motions. The paper, entitled "Microwave Oscillation Generators Using Velocity Modulated Electron Beams," presented the main results of the elementary theory of three kinds of velocity-modulated tubes, namely, the monotron, the Klystron, and the reflex Klystron. The mono-

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tron is a tube in which a cavity resonator is placed between the grid and plate to act as a tank circuit, and a steady unmodulated electron beam is sent through the grid from the cathode with no attempt at any kind of modulation of the beam before it arrives at the control grid. In the Klystron, electrons are emitted from a thermionic cathode and are accelerated by means of a cathode potential in a beam, through the grid or cavity resonator, the buncher. After traversing these grids, electrons travel through the axis of the tube to another cavity resonator, the catcher.

Use of Reflex Klystron

The reflex Klystron has been used principally as a low-power tube and is especially useful as the local oscillator of a heterodyne receiver. Electrons are accelerated from the cathode by a voltage between the cathode and a single cavity resonator, where they experience velocity modulation. They are then repelled by a negative reflector voltage and revert back to the grid of the resonant cavity.

After a mathematical analysis, it was shown that the slowness with which electrons travel at ultra-high frequencies rules out the possibility of making oscillators designed on the principle of a class C amplifier or oscillator. It is for this reason that oscillators using velocity modulated beams have been so thoroughly investigated within recent years.

A paper, "The Principles of Klystron Amplifiers," by Dr. R. O. Haxby of Sperry Gyroscope Co., dealt with the fundamental principles governing the operation of Klystron amplifiers rather than the description of any particular tube. It was shown that there are two principal reasons for the unsatisfactory operation of amplifiers at very high frequencies: (1) the transit time of electrons to pass the control grid takes an appreciable part of a cycle of the high frequency, thereby causing loading and loss of gain; (2) the size of the electrodes and circuit becomes comparable to a wavelength, making it difficult to design efficient circuits and obtain radio-frequency power.

In the Klystron amplifier, the transit time of electrons is used to advantage rather than to disadvan-

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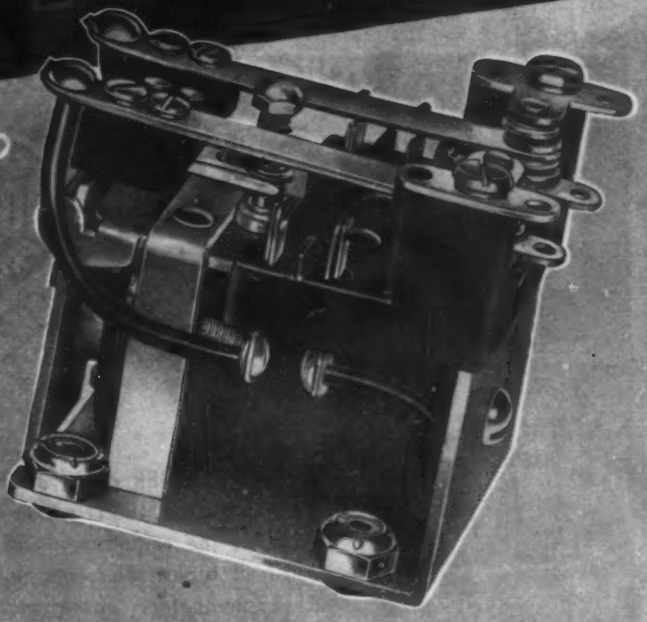

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tage, with the resonant circuits designed as an integral part of the tube. The Klystron consists of an electron emitting gun, a smoother grid, a pair of buncher grids in one cavity resonator, a pair of catcher grids in another cavity resonator, and output and input terminals to the two cavity resonators.

Operation

In the operation of this tube, a small amount of power is fed into the buncher resonator through its coupling loops. This power builds an alternating voltage across the buncher gap. Assuming that the electrons in the beam take only a very small fractional of a cycle to get through the resonator, they either gain or lose an amount of energy equal to the electronic charge times the instantaneous voltage across the gap. Consequently, each electron is speeded up or slowed down as it passes through the grid, by an amount depending upon the instantaneous voltage of the resonator. This process is called "velocity modulation."

Bunching

A beam of electrons which has been velocity modulated will be density modulated or "bunched" at some point within the tube. This bunched grouping of electrons travels down the tube until it reached the grid of the catcher, where the electrons are slowed down in going through the catcher when the voltage is in a direction to slow them down. That is, the electron beam has lost energy, on the average, because of interaction with the field of the resonator. This energy loss by the beam must have gone into the catcher resonator to maintain its oscillation and supply power to an external load. Thus the catcher resonator extracts some energy from the beam. Since there are always some electrons which are not in the bunch, there will always be some electrons speeded up by the catcher, so the efficiency of the tube is limited to a value considerably less than 100 percent. A mathematical derivation of the process shows that it cannot exceed 58 percent.

Dr. Haxby provided a mathematical and graphical analysis of the behavior of the Klystron amplifier, noted some of the factors which

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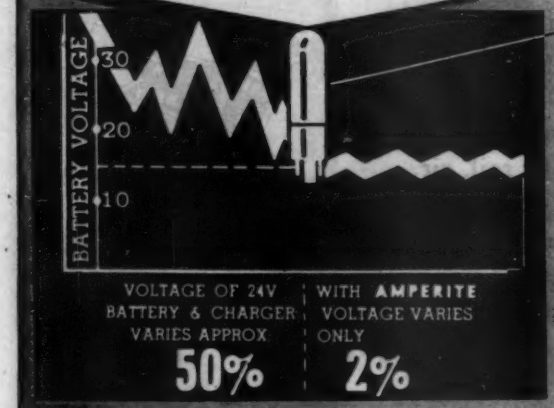

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were not taken into the mathematical theory and explained how these would modify the behavior of the Klystron amplifier.

Cascade Resonators

Since the gain of a Klystron amplifier may be increased by adding more resonators, a very high gain amplifier may be constructed, using a single cathode and electron beam. An n-stage cascade amplifier with $n + 1$ resonators will have a gain which is approximately the nth power of the gain of a single-stage amplifier. The last stage of a cascade amplifier is used as a power amplifier with optimum bunching in the last drift space. Thus, a Klystron tube may serve as a combined high-gain amplifier and power amplifier.

Amplitude modulation may be produced by changing the magnitude of the beam current, and phase modulation is produced by varying the beam voltage around the point of optimum bunching. Phase modulation is also accompanied by a small amount of amplitude modulation unless special precautions are taken to avoid the latter.

A thorough analysis of vacuum-tube frequency-converting devices for use at moderately high frequencies was given by Dr. Harry Stockman, Cruft Laboratory, Harvard University, in a paper, "U-H-F Converters and Conversion Diagrams." Using mathematical as well as graphical methods of analysis, Dr. Stockman showed that a broadcast frequency converter functions as a fixed path-of-operations device or as a changing path-of-operations device. As the frequency is increased, the conventional changing path-of-operations device ceases to function properly, and the action of the other type of converter becomes more and more intricate. This action usually cannot be explained by a few measured characteristics and simple additional mathematical analysis.

Present Design

Modern converter theory deals with the transconductance characteristics of the mixer-oscillator combination rather than the current-voltage characteristics of the mixing device. The variation of

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RESISTANCE WIRE

ALLOY "C": Nominally contains 60% nickel, 15% chromium, and balance iron. High resistance to oxidation and corrosion. Widely used in resistances for radio and electronics, industrial, and domestic equipment. Operating temperature up to 1700° F. Specific resistance 675 ohms/C.M.F.

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RESISTANCE WIRE

ALLOY "D": Nominally contains 30% nickel, 15% chromium, and balance iron, and has a specific resistance of 600 ohms/C.M.F. Pure Monel and nickel resistance wire also obtainable.

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ALLOY "45": Alloy of 55% copper, 45% nickel with a constant electrical resistance over wide range of temperatures. Specific resistance 294 ohms/C.M.F.; temperature coefficient 0.00002 ohms per degree F; 32 to 212 degrees range. Used in winding of precision resistors.

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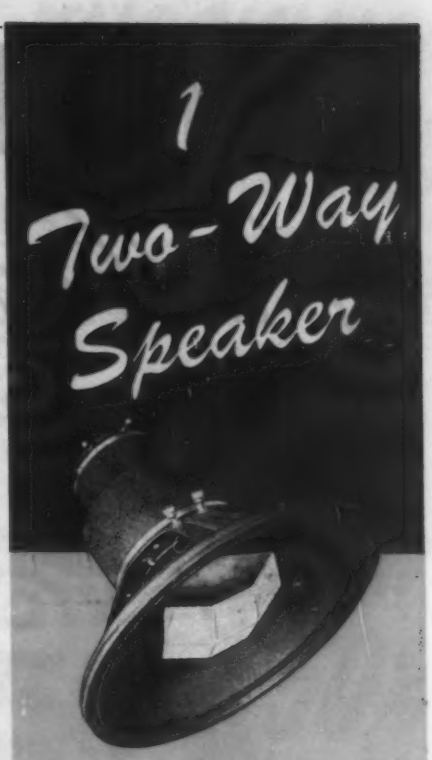
Note: All alloys are produced in high-frequency type furnaces, and are furnished bright, dull, or oxidized finish, also with enamel, silk, or cotton insulation.

transconductance from this point of view may be written in the form of a Fourier analysis containing a constant term and an infinite number of harmonically varying terms whose frequency components are integral multiples of the oscillator frequency. Accordingly, a frequency converter may be considered as a device with periodically varying transadmittance or transconductance, the periodicity of which determines the frequency of each possible output component.

Converter design is frequently carried out by means of measurements only, or by means of cut-and-try methods backed by experience. The amount of computation that enters into such a procedure depends upon the nature of the work, the importance of this design, and similar factors of engineering importance. An experimental method, using conversion diagrams, make possible the theoretical investigation of the behavior of mixer circuits under various conditions of operation. The experimental and graphical techniques for establishing such conversion diagrams were outlined, and the result of measurements on diode converters at a frequency of 7 Mc or higher were presented. The paper was primarily concerned with a discussion of the mechanism by which satisfactory frequency conversions at ultrahigh frequencies could be accomplished by a combination of mathematical, experimental, and graphical methods of analysis.

The making of ultra-high-speed radiographs, using exposures of the order of one microsecond, requires the passage of electron currents of from 2,000 to 3,000 amperes, according to Dr. C. M. Slack of Westinghouse and Edward R. Thilo of Frankfort Arsenal, Philadelphia, who delivered a paper, "Field Emission Applied to Ultra Speed X-Ray Technique." It is not practicable to obtain such large currents from a tungsten filament, but such currents can be supplied by an electron source utilizing field emission from a cold-cathode electrode in a high vacuum. While investigating the phenomena of spitting or backfiring, with a capacitor discharge machine, it was found that the magnitude of bursts of current were surprisingly large. The problem of controlling these currents so that



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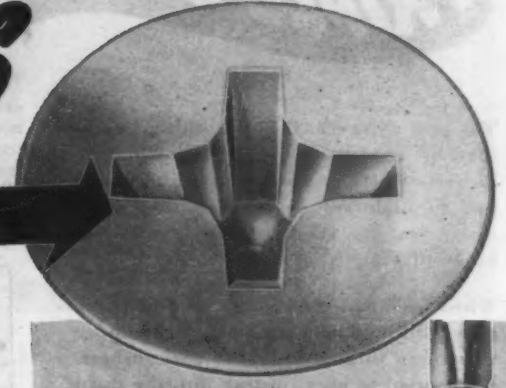

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PHILLIPS *Recessed Head* SCREWS

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Faster Starting: Driver point automatically centers in the Phillips Recess . . . fits snugly. Fumbling, wobbly starts, slant driving are eliminated. Work is made trouble-proof for green hands.

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Easier Driving: Turning power is fully utilized. Workers maintain speed without tiring.

Better Fastening: Screws are set-up uniformly tight, without burring or breaking of screw heads. The job is stronger, and the ornamental recess adds to appearance.

IDENTIFY IT!

Center corners of Phillips Recess are rounded . . . NOT square.

Bottom of Phillips Recess is nearly flat . . . NOT tapered to a sharp point.

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American Screw Co., Providence, R. I.
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Pawtucket Screw Co., Pawtucket, R. I.
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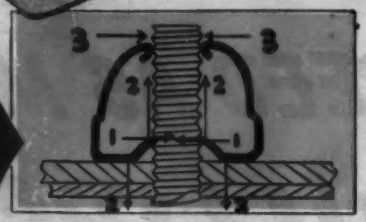
NEW TYPE NO. 6NAO SELF-LOCKING PALNUTS

With the TRIPLE GRIP

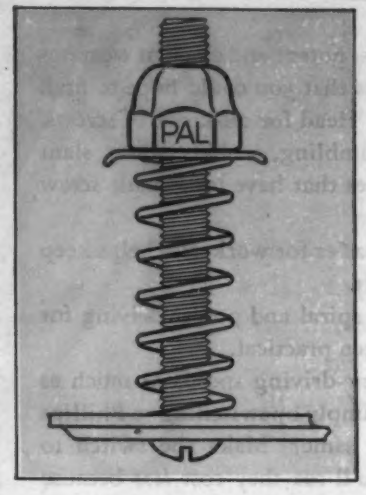


When the Type 6NAO Palnut is tightened, its arched, slotted jaws grip the bolt like a chuck (1-1), while spring tension is exerted upward on the bolt threads and downward on the part (2-2), securely locking both. A third grip is exerted around the top of the bolt by spring tension at 3-3.

The new Type 6NAO Self-Locking Palnut may be used as a one-piece locknut to securely fasten parts—or as an adjusting nut to maintain accurate settings anywhere on the screw. (See typical use herewith.)

When used as a fastening, the full triple grip is utilized to keep parts tight under vibration, without need of lockwashers. When used as an adjusting nut, the third gripping action (3-3) locks it firmly in position.

Type 6NAO Palnuts are single thread locknuts, made of tempered spring steel. Light in weight, low in cost, easily, speedily applied. Send details of your assembly for samples and suggestions. Write for new data sheet and copy of Palnut Manual No. 2, giving information on all types of Self-Locking Palnuts.



Adjusting Nut on Relay

THE PALNUT COMPANY

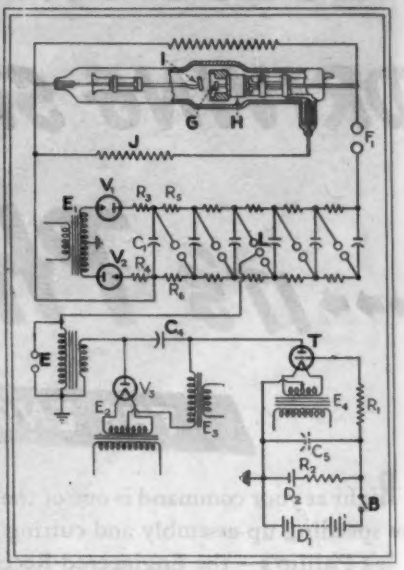
77 CORDIER ST. IRVINGTON 11, N. J.

Self-Locking PALNUTS

the electron stream would strike a suitable anode with the necessary velocity to produce x-rays was next undertaken.

Arc as Cathode

A control electrode placed in close proximity to a sharp edge gave promise of fulfilling the necessary conditions. The diagram shown may be used to explain the method of operation of the device. The capacitors are charged by the transformer E_1 through rectifiers V_1 and V_2 to a voltage somewhat less than that required to break down the spark gap L. Simultaneously, capacitor C_4 is charged to about 1,000 volts. When the circuit is broken



Circuit developed for utilizing field emission to provide heavy electron currents in high-speed radiography

at point B, the charge on the grid of thyratron T leaks off, permitting C_4 to discharge through the primary of induction coil E, which gives a sufficient impulse to the high-voltage circuit to cause the gap L to flash over. This causes the surge generator gaps to break down, which impresses a high voltage inside the x-ray tube between points G and H. Electrons are drawn from G and this initial discharge becomes an arc between points G and H which spreads out into the focusing cup and becomes a virtual cathode at apparently unlimited current-carrying capacity. Due to the action of resistance J, the discharge transfers to the anode, I, with consequ nt production of x-rays. The properties of

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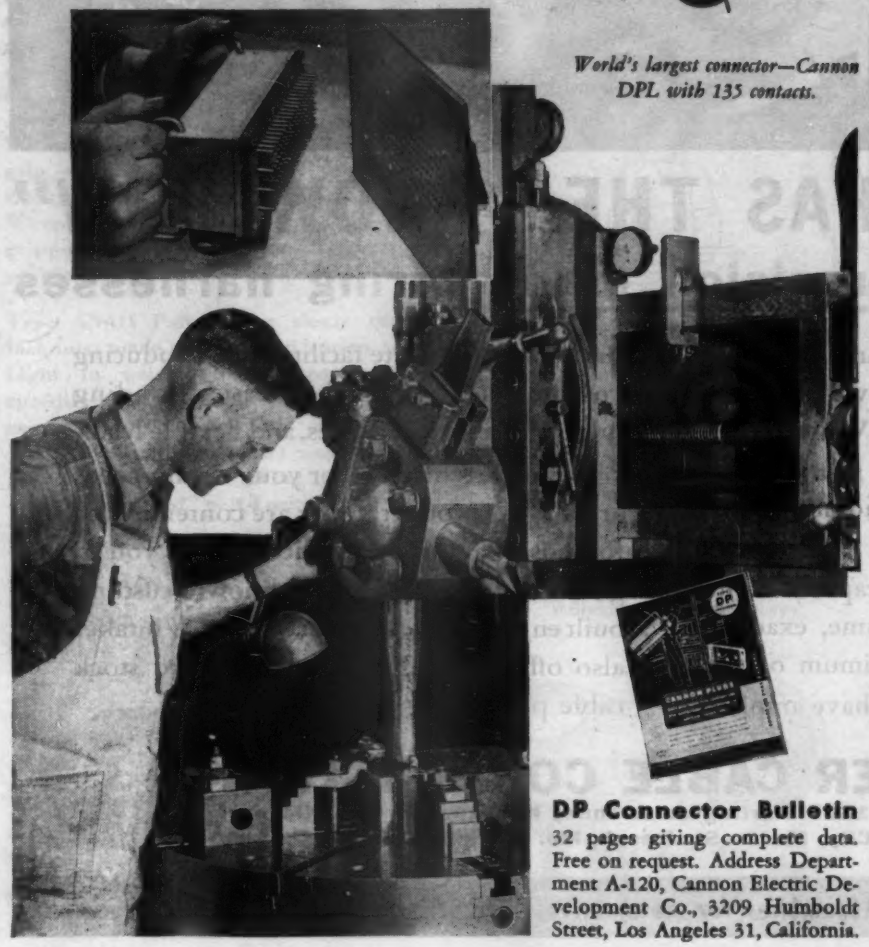

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DP Connector Bulletin
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such a field emission should find application to electronic devices other than x-ray tubes, particularly where pulse techniques are important.

X-Ray Stress

The very short exposures possible with this tube and generator have permitted sharp radiographs to be made of extremely rapidly moving objects. The chief use of this development so far has been in ballistics research to observe the realignment of component parts inside a bullet when it is fired. A stationary x-ray picture is taken of the bullet, which is then fired and a high-speed x-ray picture taken of this same bullet in flight. A comparison of the two x-ray pictures reveals any shift of the component parts which has taken place.

Dr. Wesley Roberds, in a talk "The Use of Radio Frequencies to Obtain High Power Concentrations for Industrial Heating Applications," stated that the use of radio frequencies makes possible the application of power to metal objects in concentrations up to 100 kw per sq in. Under favorable conditions, this may represent the expenditure of 2,000 kw of power per cu in. of material being heat treated. A study of heat distribution in metals treated by high-frequency furnaces illustrates two important facts: (1) the heating time must be very short (in the order of microseconds) if the high temperatures are to be closely confined to the volume occupied by the induced current; (2) the greatest heating effect occurs at the boundary between magnetic steel and its nonmagnetic form when magnetic materials are treated. As the steel is heated above the Curie temperature, the maximum heating effects move inward.

Practical Conditions

The optimum frequency is determined principally by the size and shape of the work to be heated. In general, the smaller the piece, the higher is the frequency which should be used. Power concentration is obtained with the use of electronic generators having output powers up to 200 kw at 400 kc. For dielectric heating, the power concentrations are much lower than in induction heating but it is usually

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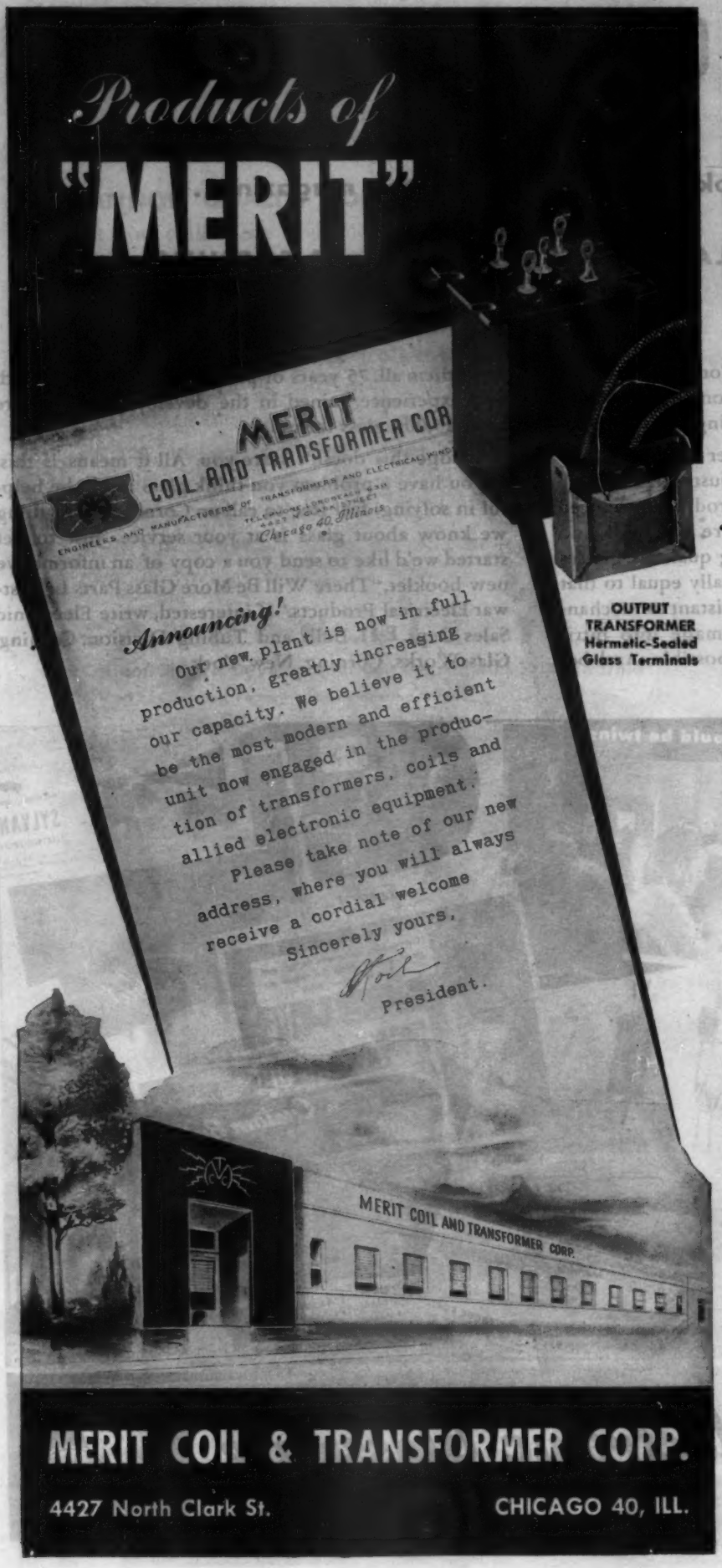
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possible to apply energy at far higher levels. Since the electrodes are good electrical conductors, they are not heated by the current and therefore are generally cooler than the work. Thus the surfaces of the work are usually kept cooler than the interior and the conduction of heat from the work to the electrode is one of the limiting factors in producing high energy concentration of work.

A complete description of a two million volt mobile x-ray unit was described in a paper by Dr. E. E. Charlton and W. F. Westendorp of the Research Laboratory of General Electric Co. The new unit consists principally of a low-frequency resonance transformer with a coaxially mounted multi-section x-ray tube within, both contained in a steel tank and insulated with compressed gas. The x-rays are generated at a target mounted in the end of a chamber projecting from one end of the tank. The unit is 5 ft in diameter and 8 ft in length and weighs 5,000 lb. It is mobile in the sense that it can be readily moved by crane and positioned for operation at any angle by pushbutton control of fractional-horsepower motors.

Transformer Construction

The transformer has a low-voltage winding consisting of two flat coils of rectangular wire, and a high-voltage coil consisting of 243 thin flat sections spaced apart for cooling. The resonance principle of operation makes an iron coil unnecessary in this type of transformer and the central space of the high-voltage coil is occupied by the x-ray tubes, thus facilitating the making of connections to various tube electrodes and providing the benefit of electrostatic shielding by the transformer coil. The multi-section high-voltage coil serves a quadruple purpose; (1) to generate voltage; (2) to grade the potentials so as to prevent creepage; (3) to shield the x-ray tubes electrostatically from the grounded tank; (4) to support the grounded shield mechanically.

A 24-section x-ray tube, which seals off the pump for operation at two million volts, was especially designed for this resonant transformer. It has a filamentary cathode, a copper-backed tungsten tar-

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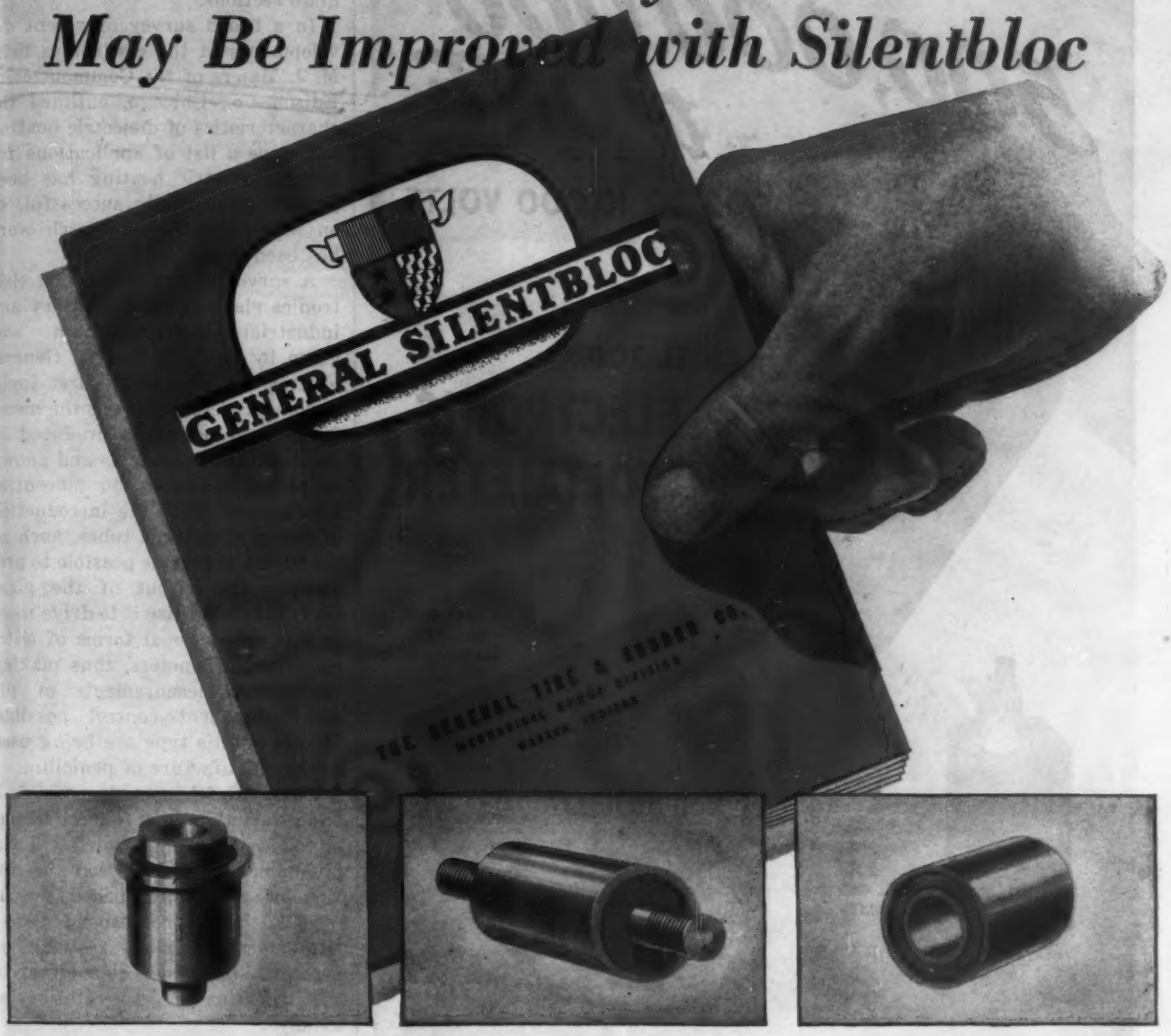

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get and accelerating cylindrical electrodes in each of the intermediate sections.

In a broad survey of recent developments in the electronics field, M. J. Maiers of the Commonwealth Edison Co., Chicago, outlined the characteristics of dielectric heating and gave a list of applications for which dielectric heating has been proved economically successful, or on which extensive research work has been done.

A survey of the role which electronics plays in the laboratory and industrial instrumentation was given by H. D. Middel of General Electric Co. One of the first applications of electronics was the measurement of potentials produced by the dissociation of acids and known as pH or hydrogen ion concentration meters. With the introduction of low grid current tubes, such as the FP-54, it became possible to preamplify the output of the glass electrode and utilize it to drive more or less conventional forms of automatic potentiometers, thus making continuous measurements of pH and subsequent control possible. Meters of this type are being used in the manufacture of penicillin.

Electronics has made possible a wide variety of servo-mechanisms or follow-up systems which will amplify small torques so that the motion of a heavily loaded output mechanism will correspond closely without imposing any restraint or reaction upon its motion either in the direction of its rotation or axially.

Gas Analysis

Electronics has introduced an entirely new principle of gas analysis and has provided a means for obtaining higher accuracy and precision as well as automatizing the measurements. One method of analyzing gas is by means of the mass spectrometer, described by Hipple in the November 1943 issue of ELECTRONICS. To the other forms of gas analysis, using absorption in the infra-red and ultraviolet regions and variation of thermal conductivity, may be added a new method depending upon the variation in molecular weight or density of the gas with changes in its constituents. A column of the gas under analysis is excited by the output of an audio oscillator, and the frequency at res-

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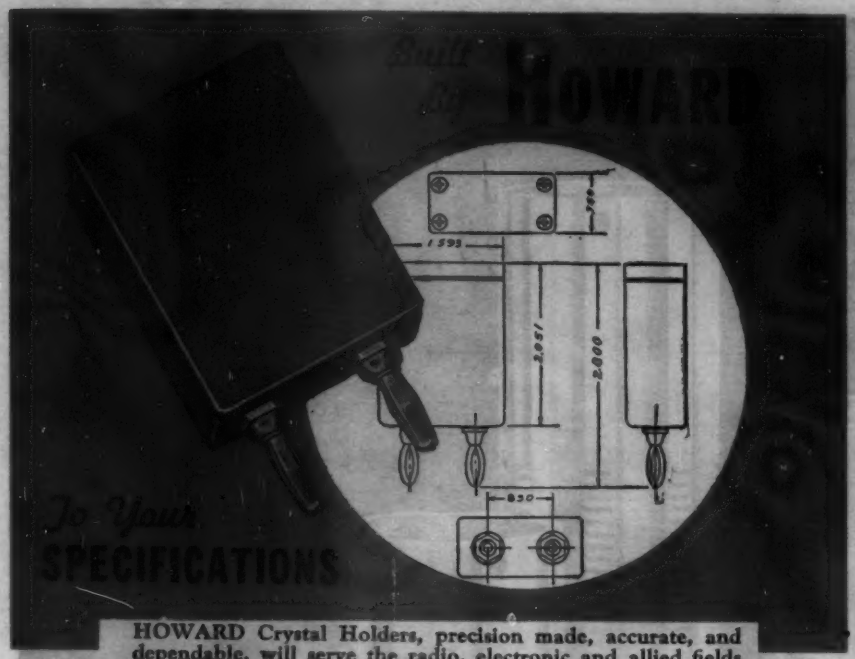

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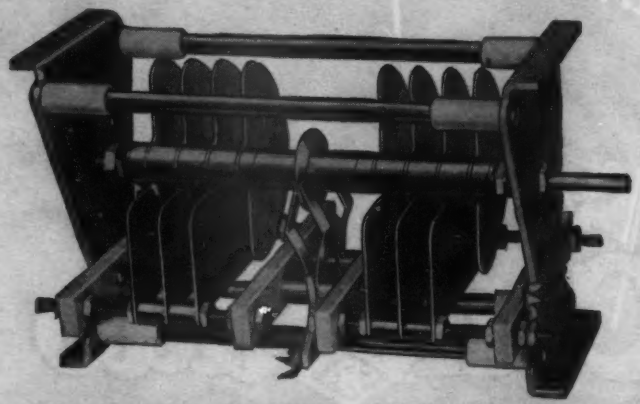

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onance or the phase shift is measured by electronic means. Through the use of such an instrument, explosive mixtures may be avoided in the operation of the hydrogen cooled alternator.

Measuring Pressure

Pressure may be measured by any one of the following three methods: (1) by balancing an unknown pressure against a known force; (2) by measuring the deformation of an elastic membrane; (3) by utilizing a quantitative change in the physical properties of materials. Electronic devices may be applied to any or all three of these methods of pressure measurements. One interesting application of the third group is that in which the thermal conductivity of a gas varies with pressure to effect a change in resistance or temperature of a wire filament supplied with a constant current and immersed in the gas.

Mr. Middel pointed out that it is not improbable that a pressure-responsive element like a spring-loaded bellows or a diaphragm might be incorporated in an electronic tube to modify the plate-to-grid and cathode spacing and provide a plate output proportional to pressure. Attempts have also been made to produce variable-mu tubes by moving the grid within the tube by mechanical means.

In measurements of the flow of fluid, the pressure differential may be measured by a bellows type of pressure-measuring element in which the motion of the free end of the bellows may be used to alter the inductive relations in an adjustable iron-core transformer. The variation thus produced may be regarded as a signal which may be transmitted over a pair of wires to an electronic servo mechanism to accomplish any desired result.

A considerable portion of the paper was devoted to the measurement of temperature by means of the thermocouple, resistance thermometry, radiation pyrometry, self-balancing potentiometers, photoelectric and electronic potentiometers. A photoelectric potentiometer using a reflecting-type galvanometer and phototube combination is shown in the circuit diagram. Light variations on the type 930 phototube produce grid voltage variations on the 6J5 triode which in turn deflects

TUBING . . .
of Spherical Importance

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Precise Instruments, vital to all Communications, must depend upon accurately-made, positively balanced Pointer Tubing. Today Precision Tube Company supplies this high grade Aluminum Alloy Pointer Tubing to over 80% of the Instrument Manufacturers in the free land. There must be a reason.

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Metal Shielded Wire — insulated wires shielded with Seamless Aluminum or Copper Tubing — offers the only positive protection against Moisture, Electrical Interference and Mechanical damage. It is a MUST for dependable Electronic Equipment where failure cannot be tolerated. Made in a wide variety of sizes and combinations.

Geographically and mechanically men today are more fully aware of "spherical importance" than ever before.

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We at Precision Tube Co. are specialists in spherical accuracy. Aluminum, brass, copper and nickel tubing manufactured to close tolerances. Metal Shielded Wire for electronic and Radar devices. Precision Tubing for electrical instruments of all types.

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PORTABLE POWER PROBLEMS

THIS MONTH—G-E MODEL "B" ELECTROCARDIOGRAPH

HIGH SENSITIVITY and standardized operation characterizes the General Electric Model "B" Electrocardiograph which assists doctors in quickly establishing accurate diagnosis and prognosis of heart conditions. A true photographic record of minute change in heart potential waves is given by this remarkable lightweight, *battery-powered* instrument. As a result, it quickly and economically makes available information that would otherwise be very difficult to obtain.

BATTERY COMPARTMENT, shown upper left, houses the power heart of the G-E Model "B" Electrocardiograph (Burgess "A" and "B" Batteries are standard equipment.) General Electric descriptive literature emphasizes that "batteries provide the most dependable source of power—always smooth." Battery power assures operation anywhere—independent of commercial electric supply. Burgess engineers are constantly adapting special-purpose batteries for specific commercial and industrial requirements. Let them solve *your* portable power problems. *Send coupon for free Engineering Manual.*

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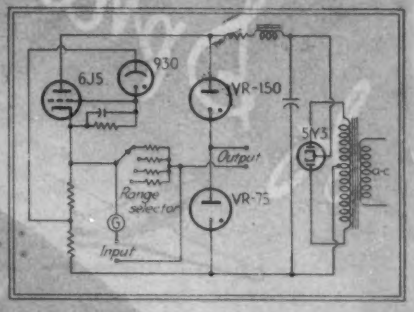
BURGESS BATTERIES

the pointer of the galvanometer, *G*.

The tube is used as a variable resistance in one arm of a Wheatstone bridge. Light variations on the phototube thus unbalance the bridge. In series with the load is a resistor so arranged that a voltage proportional to output current is fed back in opposition to the input voltage. This causes the galvanometer to take up a stable position as some function of the remaining un-



Circuit of a photoelectric potentiometer that operates on light variation for measuring temperature

balanced current. The magnitude of this current is not constant, but varies with the basic element sensitivity, the kind of optical system and input voltage.

The present status of the use of fluoroscopic rather than radiographic methods of examining industrial products was reviewed by Dr. Scott W. Smith of Kelley-Koett Mfg. Co. in a paper, "Industrial Fluoroscopy of Light Materials," in which attention was directed to various factors contributing to the success of this method, and the outlook for future developments was discussed. It was pointed out that the possibility of using fluoroscopy as a means of relieving radiography of part of the burden of industrial inspection, where the degree of sensitivity required is within its limitations, is being given serious consideration. It seems quite reasonable to expect fluoroscopy to augment rather than to supplant radiography.

Present Applications

Since industrial specimens do not necessarily require a short exposure, and are not subject to movement during exposure, these advantages have permitted the development of fluoroscopy for many industrial applications. In fact, the fluoroscope has been used for quite a

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AS the giant Boeing B-29 Superfortress carries destruction to Japan, the pride of America echoes in the roar of her mighty engines. And to the ingenious Boeing engineers who created her, the Nation owes a great debt.

We have special reason to be proud of the B-29's performance, for Boeing incorporated no less than 300 permanent magnets in her magnetos, instruments, compasses, audio speakers, radio equipment, automatic pilot, remote gun controls and other vital devices.

It is our job to manufacture a large portion of these permanent magnets, as well as those for other types of war equipment. And our specialized designing skill has often resulted in increased efficiency and lower costs.

Our engineers are in an excellent position to help solve your permanent magnet problems. Write for a copy of our "Permanent Magnet Manual."

ARMY E NAVY

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Ten channels: Galvanometers available covering wide range of characteristics: Daylight loading of 6-inch paper or film: Recording speeds quickly adjustable: Automatic record length control: Automatic record numbering: Simultaneous viewing and recording: All controls convenient on top panel. Early delivery. Hathaway Instrument Co., Denver, Colorado.

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Hathaway INSTRUMENTS

long time for such applications as spotting a foreign body in packaged food, candy and tobacco, as well as sorting fruits, determining the filling level in cans, the shape and position of the core of golf balls, or the alignment of the elements in electron tubes.

After a historical resumé of fluoroscopic methods and screens, it was shown that an improved zinc sulfide screen, treated in such a way as to reduce afterglow, is commonly used at the present time and that photographs of the fluoroscopic image on small films has been generally employed in induction centers during the war with a considerable saving in film over the usual 14 x 17-in. radiograph previously employed.

It was concluded that the widespread use of radiography for the control of foundry technique and the inspection of light alloy castings can be further augmented by the use of fluoroscopy with a reduction in the cost factor.

In a paper entitled, "Aircraft Electronic Applications" A. P. Upton, Minneapolis-Honeywell Regulator Co., described a complete electronic control system as used in modern aircraft. The electronic turboregulator and the electronic autopilot forming the major parts of this system were described in detail in the May 1944 and Sept. 1944 issues of ELECTRONICS respectively.

A paper was presented by John M. Cage of Allis-Chalmers Mfg. Co. entitled "Negative Feedback Amplifier Theory Applied to Regulators." The paper considered the mechanical problem of regulator operation, which may be most conveniently solved by the mathematics originally developed in connection with electrical theory. Such a procedure requires the necessary transformations of the terms of the dynamical differential equations from the physical concepts of one system to the physical concepts of another.

The paper also outlines an experimental procedure for measuring and studying the frequency responses of actual systems employing regulators.

W. R. Mehaffey, of Armour Research Foundation, opened the treatment of his paper, "Strain Gage Amplifier Design," by a discussion of the advantages of resis-

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Engineered Dielectric Materials

KA-44

DIAMOND
Vulcanized Fibre

The DIAMOND Vulcanized Fibre part illustrated is a handle for a welder's torch. It is made from tubing. DIAMOND Vulcanized Fibre is used for this part because DVF is tough, strong and light in weight... because it insulates electrically and thermally. The handle is economically made from DVF because DVF is readily machined, formed, spun, sawed or otherwise fabricated. For complete technical data on this C-D NON-Metallic, write for catalog DF.

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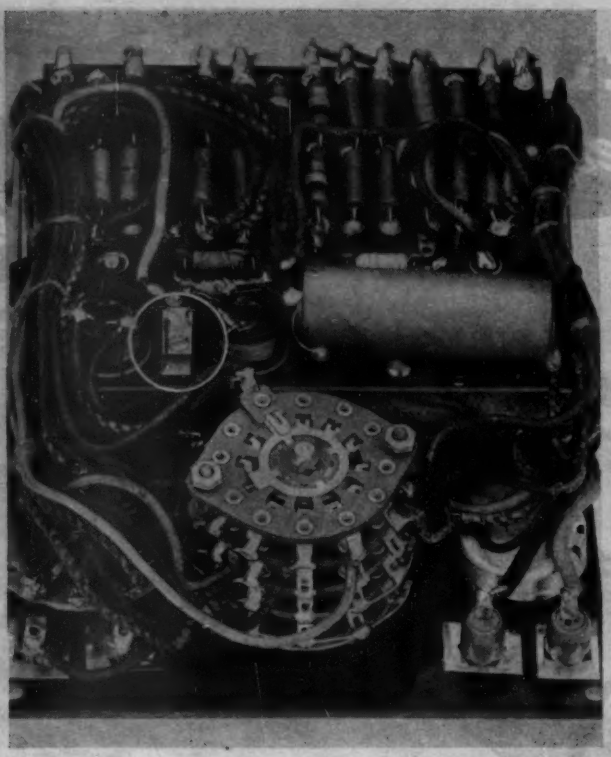
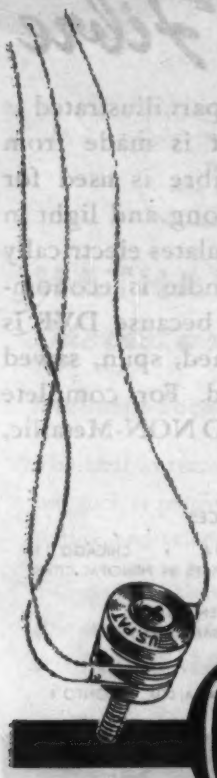
Photo courtesy of Simpson Electric Co. Chicago, Ill.



Conant's standard midget (series 160) LEADS A 3-WAY LIFE!



Yes, indeed, the standard midgets of the Conant family (160" diameter discs) are versatile. The unique full metal case protects the rectifier assembly from damage and permits mounting in any of three positions with a single screw. Combining the three positions with angular mounting permits the leads to extend from the rectifier in almost any direction. Thus, one standard rectifier serves for all models. Further protection is provided by a special moisture proof seal.

Design and construction of Series 160 are the result of years of experience and close cooperation with instrument manufacturers.

For all applications requiring high sensitivity operation over an extended frequency range, you can count on Conant's Standard Midget—Series 160.

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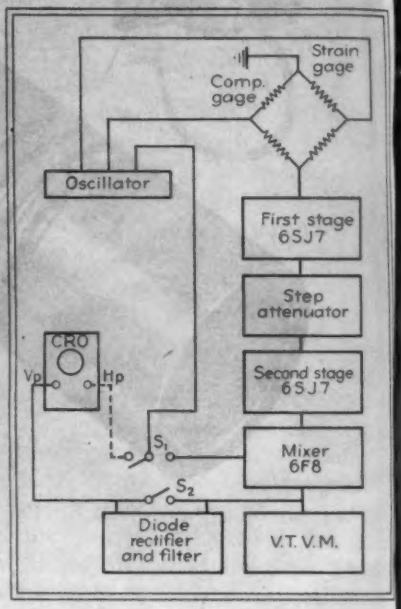
4214 Country Club Dr., Long Beach 7, Cal.
4205 N.E. 22nd Ave., Portland 11, Ore.
Caixa Postal 930, Sao Paulo, Brazil
50 Yarmouth Rd., Toronto, Canada

tance strain gages for indication.

The electrical circuits used with strain gages are of two general types, the amplitude-modulated system and the a-c potentiometer circuit. The amplitude-modulated system is used at low frequencies and for static measurements, whereas the potentiometer system is primarily used for dynamic impact studies.

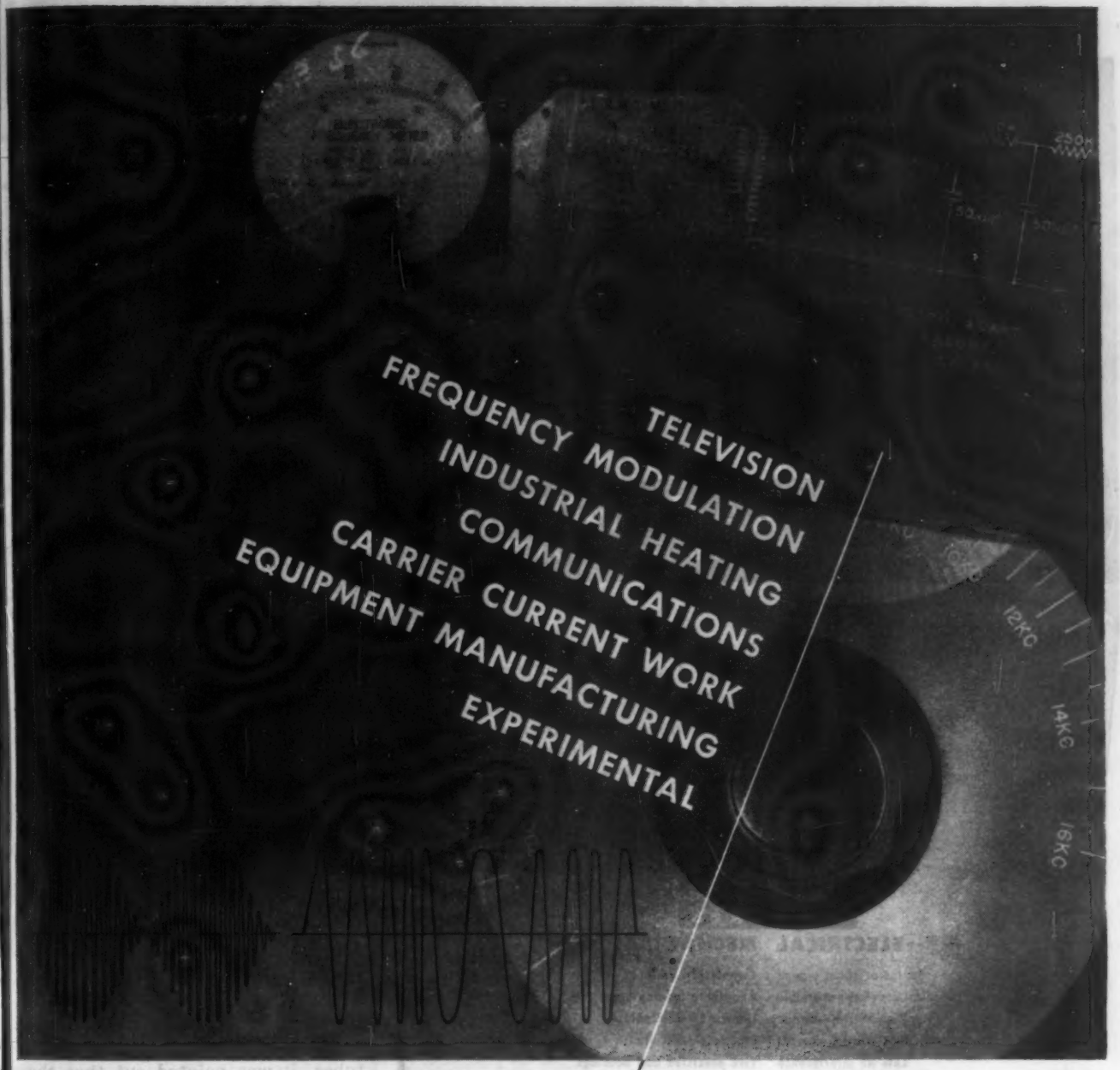
A block diagram of a circuit suitable for measuring mechanical strain by means of strain gages in a bridge circuit is shown. The resistance in one arm of the bridge is the strain gage, while a complementary gage is located near the measuring gage but is mounted in such a way that it does not measure strain. A resistance could be used but the use of a complementary gage permits temperature compensations to be easily obtained. Both capacitance and resistance balance must be provided in this bridge circuit if a sharp null indication is to be achieved. The transformer for supplying power to this bridge must be carefully shielded and have balanced construction. The output from the bridge may be coupled directly to the grid of the first stage of amplification.



Block diagram of units forming a gage for measuring mechanical strain

Methods of Operation

In general, there are three basic methods of operation of this bridge circuit. In the first, adaptable particularly to static conditions, the



Post-war electronics demands new instruments

As the "era of electronics" approaches, it is increasingly evident that the need for more accurate, highly specialized instruments becomes greater. Many of the forerunners of such instruments are already perfected and in use today, but they are still under cover of strict military censorship. When these new developments and others now in the process of development are released — not all, but certainly a good many of the commonly known instruments will instantly become obsolete. In your plans for post-war activity you should make careful note of this fact, for it may save you valuable time in future plant or product conversion.

-hp- instruments are in the vanguard of these new developments. New *-hp-* oscillators, signal generators and vacuum tube voltmeters are setting new standards for rugged construction and split-hair accuracy. Technical data on these and others not yet perfected are, of course, not available today, but the time is not far off when they can be released.

In contemplating the improvement of your laboratory or the alteration of your production with post-war activities in mind, it will pay you to consult *-hp-* engineers. These new instruments may be the answer to your problem. Please give us full details so we can be of maximum assistance.

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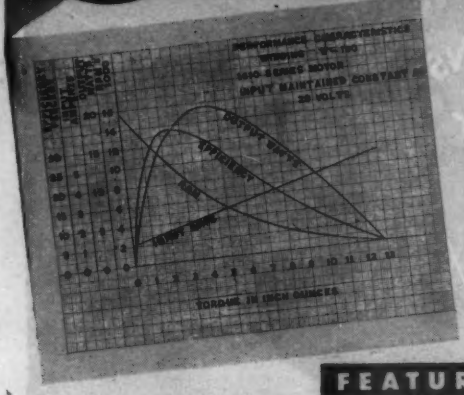
931

MOTOR DATA
No. 125

EICOR 1600 FRAME MOTOR
Torque 4.5 in. oz. at 5800 RPM



The power output of this precision motor is exceptionally high in proportion to its light weight and small size. Originally developed for numerous aircraft and portable applications, the characteristics of its performance can readily be modified for a variety of new uses.

FEATURES

ELECTRICAL	MECHANICAL
Series or shunt wound	Completely enclosed
Unidirectional or reversible	Adaptable for any mounting
High starting torque	Laminated field poles
Low starting current	Stainless steel shaft
Low RF interference	Two precision ball bearings
Armature and field windings	Mica insulated commutator
Varnish impregnated and baked	Permanent end play adjustment

1600 FRAME MOTORS		Series	Shunt
Watts Output, Int.	(max.)	22	
Watts Output, Con.	(max.)		5
Torque at 8500 RPM	(in. oz.)	3	
Torque at 5800 RPM	(in. oz.)	4.5	1
Lock Torque	(in. oz.)	12	3
Volts Input	(min.)	5	5
Volts Input	(max.)	32	32
Shaft Diameter	(max.)	.250"	.250"
Temperature Rise		50°C.	40°C.
Weight		12 oz.	12 oz.

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bridge is initially balanced before the member is strained, then rebalanced after the member is strained, the change in the reading of the calibration dial on the slide wire is then proportional to the deflection or strain. The second method of operation is the so-called voltage unbalance method in which the bridge is initially balanced before the application of the strain and the unbalanced voltage as indicated by a metering circuit is used as a measure of the strain. The third method is that in which the bridge is usually operated with an off-balance initial condition to provide an indication that the strain is either tension or compression.

The author concluded that the amplitude-modulated system provides a simple and reliable means for amplifying the output from electrical strain gages without the need for direct-coupled amplifiers. The basic problems in the design of this type of equipment for use as null system or a voltage unbalance system were treated in the paper.

Tube History

A rather comprehensive outline of the development of electron tubes was given by I. E. Mouromtseff of the Westinghouse Electric & Mfg. Co. He pointed out that although beam tubes are usually considered to be a recent development, the first practical result of electron tube research was the production of x-ray tubes in 1895 making use of the electron emission as a beam.

In discussing high-frequency tubes, it was pointed out that the first vacuum tube used in high-frequency circuits was built in 1892 by Zehnder for demonstrating Hertzian waves to large audiences. The Zehnder tube was a small gas-filled tube in which the gas discharge was triggered by high-frequency oscillation. The development of high-vacuum pumping techniques and the invention of the glass-to-copper seals by Houskeeper in 1922 gave a new impetus to the development of radio tubes. Mr. Mouromtseff anticipates tubes of 500 kilowatts as perhaps representing the ceiling for practical rating of individual sealed-off tubes, for at power greater than this, the cost of the tube will probably be out of proportion to their advantages because of design difficulties.

GLASS-TO-METAL SEALS

by the Thousand!

HUMIDITY-PROOF

SHOCK-PROOF

LEAK-PROOF

Another modern electrical development pioneered and perfected by Sprague

Pioneered many months ago by Sprague, glass-to-metal seals for Sprague Capacitors and hermetically-sealed *Koolohm Resistors have progressed far beyond any "laboratory curiosity" stage. Not only are they being produced commercially at better than 10,000 seals per day, but they have proved highly efficient both electrically and mechanically. Seal sizes range from very small up to 3" diameter. They work equally well with practically any metal including steel, brass, and monel metal, and do not require the use of glass bushings and adjacent metal rings with "matched" temperature coefficients of expansion.

There are, of course, plenty of "scientific" reasons why glass-to-metal seals of this type are not feasible. Here again, however, the allegedly impossible has simply provided the incentive for another outstanding Sprague engineering achievement. Actually, the only disadvantage to the seals so far uncovered is the fact that corona voltages are a little lower than we'd like them to be—yet this limitation only becomes a factor at voltages upwards of 25 KV. In all respects, the Sprague glass-to-metal seal answers the old problem of guarding Capacitors and Resistors adequately against leaks and moisture—and without organic bushings or other materials which might be attacked by fungus.

Today, glass-to-metal sealed Sprague Capacitors and *Koolohm Resistors are available in 8,000 electrical characteristic combinations—which is another way of saying that there is a sealed unit for every application that needs one. Details gladly sent on request.

SPRAGUE ELECTRIC COMPANY, NORTH ADAMS, MASS.

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ARMY E NAVY

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SPRAGUE

PIONEERS OF ELECTRICAL-ELECTRONIC PROGRESS

NEWS OF THE INDUSTRY

Conference notices; new television studios opened; Washington News on transformers, production of electronic equipment, broadcast power, tubes and parts

Collective Bargaining for Engineers

PROTECTION OF THE INDIVIDUAL engineer, suggests C. A. Powel, newly-elected president of AIEE, could probably be provided most effectively by an overriding association embracing all engineering and devoted specifically to the welfare of the profession as a whole and the individual members comprising it.

Speaking before the Los Angeles Section Meeting of AIEE, Mr. Powel, who is manager of headquarters engineering at Westinghouse Electric and Manufacturing Company, said that such an organization must have constant and intimate contact with the rank and file of engineers and must bring its weight to bear in community and civic affairs. "The desire for collective action," Mr. Powel stated, "is as powerful among engineers as it is among members of labor or white-collar unions." Two other plans of joint action have already been tried, but had serious shortcomings. One is the move of the American Society of Civil Engineers to have local sections act as bargaining units, while the other favors the inclusion of engineers in the general white-collar unions. However, as Mr. Powel pointed out, the first presents a number of legal obstacles and the second subjects the engineers to many decisions and rules which are clearly intended for a great majority of people doing an entirely different class of work.

Therapeutic Music

THE EFFECTS OF MUSIC on certain types of mental and nervous disorders is being determined by experiments conducted through the surgeon general of the U. S. Army and

ARMY-NAVY PREFERRED ELECTRON TUBES—SUPERSEDES PREVIOUS LISTS

RECEIVING TYPES

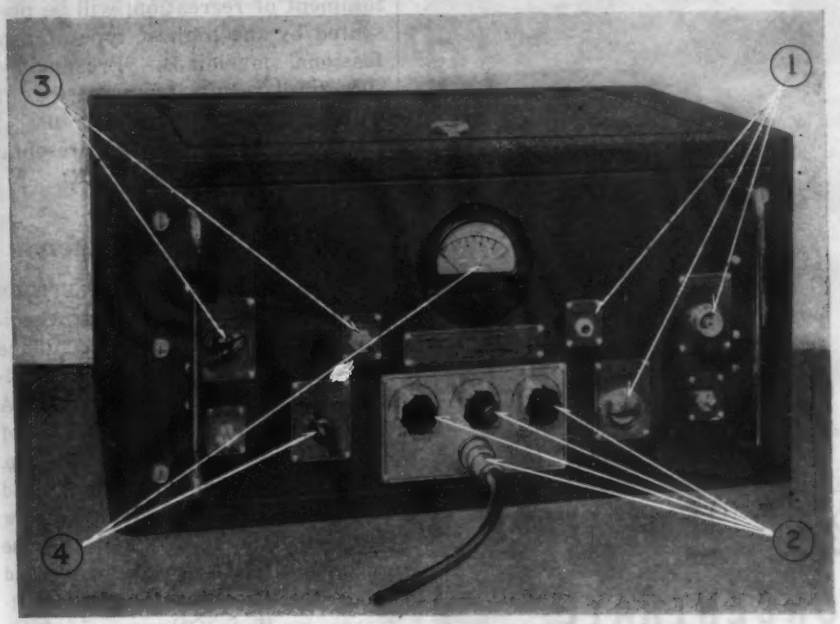
Filament Voltage	Diodes	Diode Triodes	Triodes	Twin Triodes	PENTODES Remote	PENTODES Sharp	Converters	Power Output	Indicators	Rectifiers	MISCELLANEOUS Cathode Ray	MISCELLANEOUS Crystals
1.4	1A3	1S5†	1LE3	3A5	1T4	1L4 1LN5 1S5⊕	1LC5 1R5	1LB4 3A4 3S4		1006	2AP1 3BP1 3DP1 3FP7 5CP1 5CP7 5FP7	1N21B 1N23B 1N25 1N26 1N27 1N28
5.0										5U4G 5Y3GT		
6.3	6AL5 6H6* 559	6AQ6 6SQ7* 6SR7*	2C22 2C40 6C4 6F4 6J4 6J5* 7E3/1291 9002	6J8 6SL7GT 6SN7GT 7F8	6AB7 6AG7 6SK7* 9003	6AC7 6AG7 6AJ5/ 6AK5 6AS6 6SJ7* 7W7 9001	6SA7	6B4G 6G6G 6L6GA 6N7GT/G 6V6GT/G 6Y6G	6AF6 6E5	6X5GT/G 1006	5JP1 7BP7 12DP7 12GP7 913	Phototubes 927 929 930 931A
12.6	12H6*	12SQ7* 12SR7* 14E6**	12J5GT	12SL7GT 12SN7GT 14N7**	12SG7* 12SK7* 14R7**	12SJ7* 14H7/ 14W7	12SA7* 14J**	12A6*	1629			Voltage Regulators OA3/VR75 OC3/VR108
25 and above								25L6GT/G 28D7**	991	25Z6GT/G		OD3/VR150

TRANSMITTING TYPES

Triodes		Tetrodes	Twin Tetrodes	Pentodes	Pulse Modulators	RECTIFIERS Vacuum	RECTIFIERS Gas	RECTIFIERS Grid Control	Clipper Tubes	Gas Switching
2C26A	826	807	815	2E22	3D21	2X2A	4B25	2D21	3B28	1B32/532A
2C39	833A	862A	829B	4E27	3E29	3B24	83	3C23	719A	
2C43	862A	814	832A	803	6C21	5R4GY	857B	3C31/C1B		
3C24	880	827R		837	715C	371B	866A	C5B		
CV92 (Br.)	889R	1625				705A	869B	6D4		
100TH	883A					836	872A	394A		
250TH	1625					1616		884		
304TH	8025					8016		2050		
827						8025				
811										

*Where direct interchangeability is assured "GT" and "L" counterparts of the preferred metal tube may be used.
†Diode Pentode.
**These tubes are the only types with characteristics specified for 28-volt plate supply, and may be used in this type of application. Any of the types listed under "Receiving Diodes" may be used for 28-volt plate supply applications.

• Recommended for Fast, Easy, ACCURATE Calibration of Wavemeters, Signal Generators, Oscillators, Receivers, etc.



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1. **BEAT DETECTOR UNIT** provides easy calibration with either aural or visual indication of zero beat.

2. **OUTPUT and ADJUSTMENTS** give crystal-controlled harmonic frequencies up to 2000 megacycles.

3. **MODULATION CONTROLS** permit selection of either modulated or unmodulated output as well as degree of modulation.

4. **MILLIAMMETER and SELECTOR SWITCH** facilitates easy adjustment of output controls.

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LAVOIE C-200 CALIBRATOR

The LAVOIE C-200 Calibrator is an instrument that establishes *crystal-controlled* frequencies at UHF up to and beyond 2000 megacycles. By means of a switch it cuts out 10's and produces only 40's on the megacycle frequency range . . . or by means of an Identifier, selects any ONE of these frequencies for purposes of identification. A detector and amplifier on the panel expedite the calibration of signal generators, etc. Detailed information promptly upon request.

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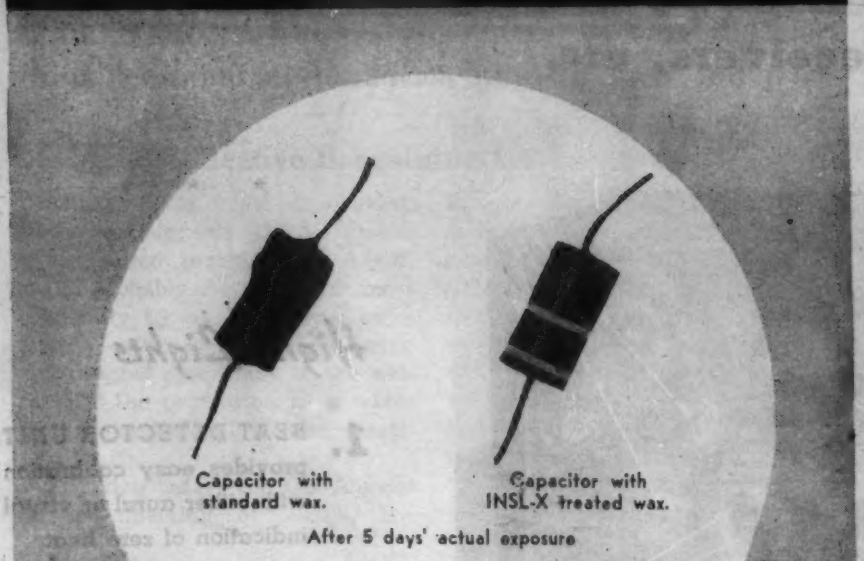

Capacitor with standard wax.

Capacitor with INSL-X treated wax.

After 5 days' actual exposure

INSL-X I-1T

FUNGICIDAL CONCENTRATE for ELECTRONIC WAXES

MEETS U. S. ARMY SIGNAL CORPS REQUIREMENTS

• Prominent manufacturers find INSL-X I-1T Fungicidal Concentrate for Electronic Waxes highly effective in the treatment of impregnating waxes for coils and parts • in the surface treatment of phenolic resistors, tube sockets, etc. • for protection of cotton wire coverings • for wax paper, labels, etc.

• INSL-X I-1T will not vaporize or lose potency at bath temperatures. *Official tests show INSL-X Fungicides are non-toxic to humans.* INSL-X fungicides are non-corrosive to metals.

For chlorinated naphthalene ("Halowax") INSL-X I-2T is recommended.

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the Institute of Applied Music. Music as an aid to treatment has been tried before, but has never been properly or adequately controlled nor has its application been evaluated scientifically.

The music itself, which in this experiment is regarded solely as an aid to treatment and not as entertainment or recreation, will be presented by the highest type of professional musicians. Presumably, successful results from these tests will point the way to wider use of recorded and transcribed presentations.

Television on SMPE Agenda

A PAPER ON PROJECTION TELEVISION delivered, at the 56th Semi-Annual Technical Conference of the Society of Motion Picture Engineers, by Dr. D. W. Epstein of RCA Laboratories and Dr. I. G. Maloff of RCA Victor Division, Radio Corp. of America. The conference, held in the Hotel Pennsylvania, New York, on Oct. 16, 17, and 18, also included a talk on coaxial cable and other facilities for television networks, by H. S. Osborne, chief engineer, AT&T.

CONVENTIONS TO COME

Nov. 2-3. National Time and Motion Study Clinic, Chicago, Ill. INDUSTRIAL MANAGEMENT SOCIETY, C. S. Becker, vice president, 205 West Wacker Drive, Chicago 6, Ill.

Nov. 9-10. Fall Meeting, Dayton, Ohio. INSTITUTE OF THE AERONAUTICAL SCIENCES, Robert R. Dexter, secretary, 1505 RCA Bldg. West, Rockefeller Center, New York 20, N. Y.

Nov. 13-14. Rochester Fall Meeting & War Radio Conference, Rochester, N. Y. ROCHESTER FALL MEETING COMMITTEE, Virgil M. Graham, chairman, PO Box 750, Williamsport, Pa.

Nov. 13-14. Annual Fall Convention, New York, N. Y. SOCIETY OF THE PLASTICS INDUSTRY, C. S. Shoemaker, meeting chairman, Dow Chemical Co., 30 Rockefeller Plaza, New York 20, N. Y.

Nov. 15-19. AMERICAN CHEMICAL SOCIETY, Chicago section. Third Bi-

New INTERNAL-PIVOT 2½-INCH PANEL INSTRUMENTS ...1 INCH DEEP

UNIFORM MAGNETIC FLUX WITHOUT SEPARATE POLE PIECES ON MAGNET
SOFT-IRON CORE
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MOVING COIL (WITH POINTER, BALANCE WEIGHTS, AND SPRINGS OMITTED TO SHOW DETAILS)

Designed for thinness—but G-E engineers took advantage of the new magnetic materials to improve performance and add unusual values. Comol was selected for the magnet, and it thus became the basic part around which the internal-pivot element was designed.

Moving element mounted on one-piece comol magnet

Extra Values That the Comol Magnet Gives You

AN air-gap flux density of approximately 2000 gausses—made possible by the comol magnet—means a magnetic field some 50 per cent stronger than that of the conventional chrome-steel magnet.

Higher Torque This greater magnetic strength provides a substantial increase in torque. Since the weight of the moving element is about the same as that of other designs, the torque-to-weight ratio is much higher.

Faster Response The greater flux density also allows the use of a larger air gap, which minimizes any tendency toward stickiness. Faster response, which is assured by the high torque and lightweight moving system, enables accurate readings to be taken more quickly.

Improved Performance Large-radius pivots and good damping are among the other good features in the internal-pivot design—a design that packs all-round fine performance in a small space. They all add up to an instrument that is well able to withstand abnormal vibration and shock and maintain its rated accuracy.

For complete information, ask our nearest office for Bulletin GEA-4064, which covers instruments for use in radio and communications equipment; or Bulletin GEA-4117, which describes those suitable for naval aircraft. *General Electric Company, Schenectady 5, N. Y.*

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Type DW-53 d-c voltmeters, ammeters, and volt-ammeters. Designed to measure voltage and current in battery and battery-charging circuits on naval aircraft. Designed to meet all applicable Navy specifications.

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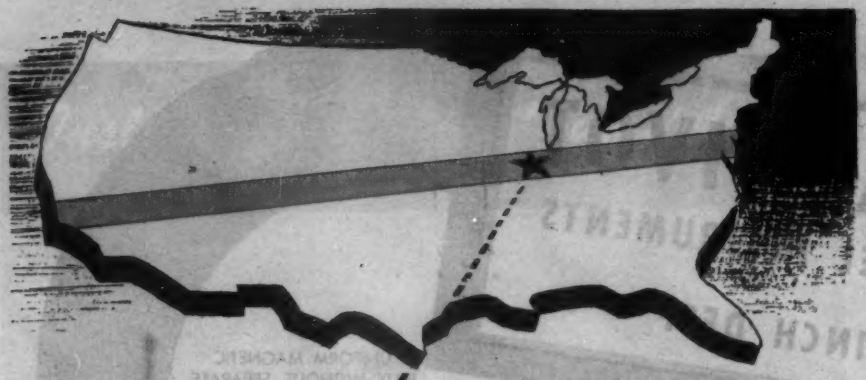

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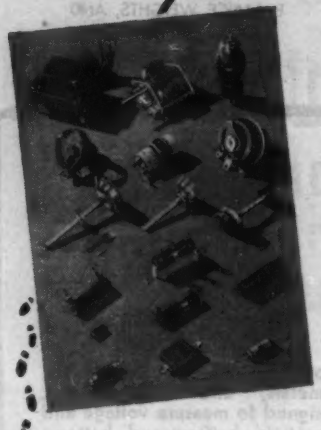

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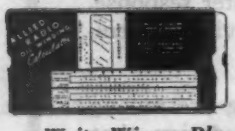

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Sockets	Receivers	Converters
Photo Cells	Training Kits	Generators
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ennial National Chemical Exposition & National Industrial Chemical Conference, Coliseum, Chicago, Ill. Marcus W. Hinson, manager, 330 South Wells St., Chicago 6, Ill.

Dec. 11-12. First Annual Conference New York, N. Y. TELEVISION BROADCASTERS ASSOCIATION, Will Baltin, secretary, 500 Fifth Ave., New York 18, N. Y.

Jan. 22-26. AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS. Winter Technical Meeting, New York, N. Y. H. H. Henline, secretary, 33 West 39 St., New York 18, N. Y.

Jan. 30-Feb. 1. INSTITUTE OF THE AERONAUTICAL SCIENCES. Thirteenth Annual Meeting, Pupin Physics Laboratory, Columbia University, New York, N. Y. Meetings Committee, 1505 RCA Building West, 30 Rockefeller Plaza, New York 20, N. Y.

Multi-Studio Television

FACILITIES of the DuMont television station in New York, WABD, have formerly consisted of a single studio alongside the transmitter, film projection room, and laboratory on the 42nd floor of a Madison-Avenue building. Recently a new studio on the second floor of the same building was put into service. Larger than the first, it still follows the principle of low-cost, small-staff, and minimum-space operation—showing the possibilities of television broadcasting for the relatively small operator.

Among problems which proved troublesome to company engineers installing the new studio were vibrations from the subway under the building and magnetic fields from the passing trains. These deflected the cathode-ray pictures three-quarters of an inch and required special shielding. A coaxial link was used between the 2nd and 42nd floors.

WASHINGTON NEWS

TRANSFORMERS. Officials of WPB have asked transformer makers to refuse orders when they cannot deliver and to notify WPB of the fact. The board will then aid in passing the orders on to other manufacturers with available capacity. Ade-

MEETING THE HIGHEST INDUSTRIAL STANDARDS

Nationally recognized engineering talent . . . sharpened by intelligent specialization . . . broadened by the exacting tests of war . . . explains, in part, PLASTIC'S amazing progress in the field of thermoplastic insulation. Also responsible are latest equipment, careful materials control, and a personnel whose loyalty and devotion is "above and beyond the call of duty." You can utilize to advantage . . . in today's planning and tomorrow's production . . . this experience and ability. Available for the asking is the "know how" which can make your product a BETTER product. You can DEPEND on PLASTIC for design . . . development . . . delivery.

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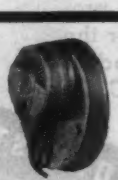
Where 60 cycle alternating current is not available; wherever interval timing and time delay operation are needed with Direct Current, the Haydon D.C. Clutch Unit functions like the proverbial charm.

It isn't magic — but its action is smooth, certain, automatic. Magnetically operated, it engages and disengages the switch operating arm, while the motor runs independently. At the end of the timed period, the clutch is still engaged, holding the contact in final position until the circuit is broken externally, when the arm resets automatically. Satisfactory operation on widely varying voltages and temperatures.

Haydon AC and DC timing motors and devices are finding even wider scope in new applications for after the war — for homes and factories — in the new automatic devices of tomorrow.



3100 SERIES HEAVY GEAR UNIT

Manufactured to your specific requirements in voltage, frequency and speed. Gear train designed for applications up to 15" lbs. torque at the output shaft.

Write today for your copy of this catalogue.

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MANUFACTURING COMPANY
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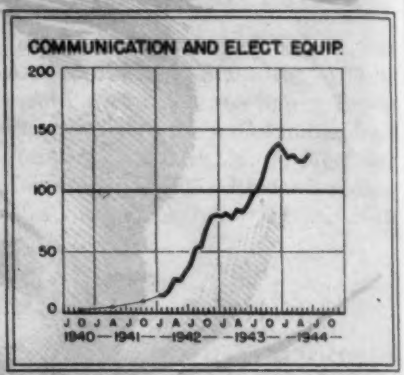
Forestville, Connecticut

quate supplies of components will be available if manufacturing facilities are thus distributed. Backlogs of transformer orders were described as slowly decreasing in most plants and reductions in delivery time anticipated. In connection with cutbacks related to VE day, even though quantities might be reduced as much as 30 percent, much of the remaining production would involve tropicalization with attendant production problems.

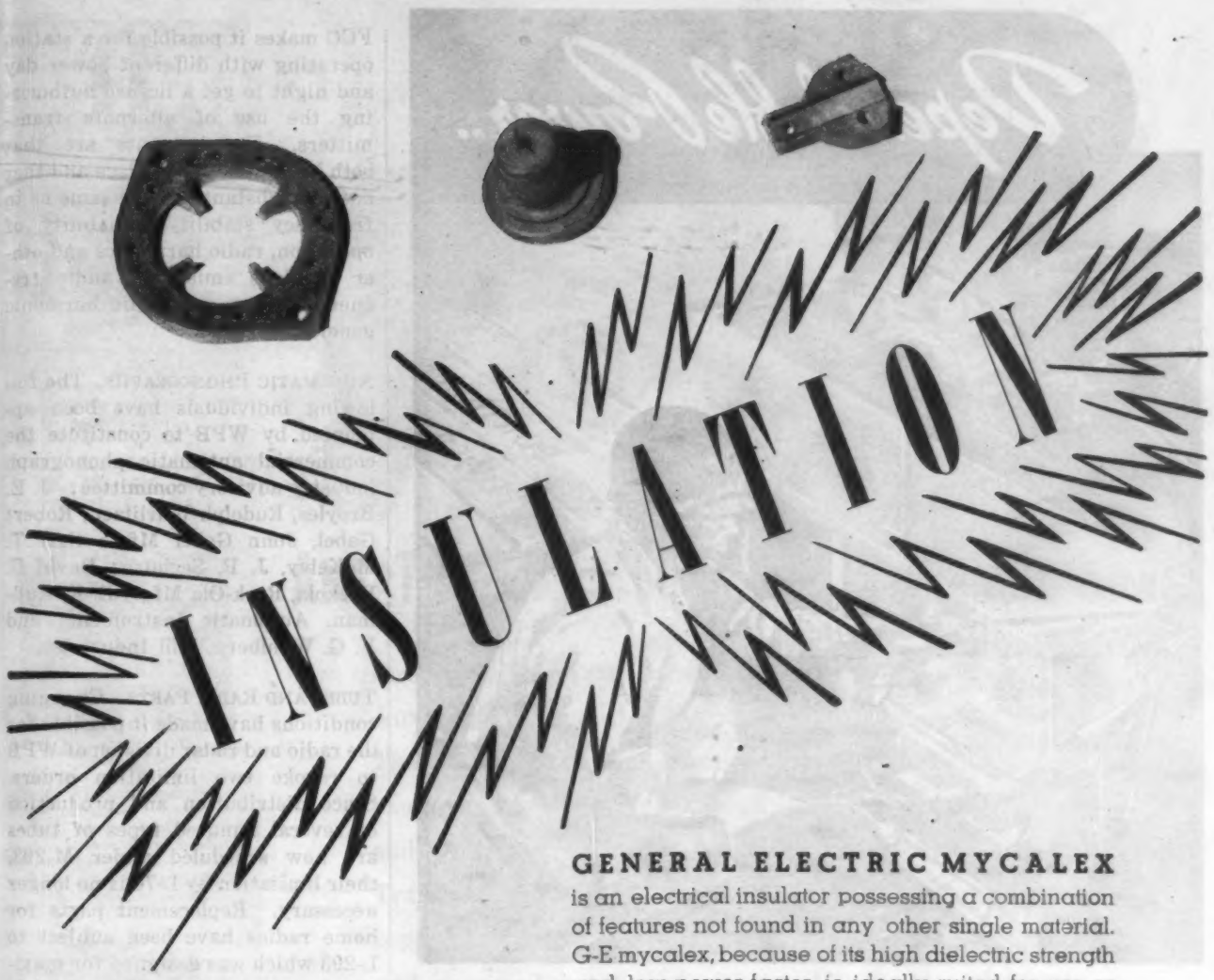
PRODUCTION INDICES. Figures released by WPB reveal June production figures in communication and



electronic equipment increasing 4 percent over May and raising the index 6 points to 130. See chart. Airborne equipment led the way with an increase of 8 percent. Ship equipment remained at the May level while ground equipment went up 4 percent.

RADIO PARTS COMMITTEE. OPA announces a radio parts manufacturers' industry advisory committee consisting of: Octave Blake, Cornell-Dubilier Electric; Samuel I. Cole, Aerovox Corp.; Monte Cohen, F. W. Sickles; Russell E. Cramer, Radio Condenser; Allen Fritzche, General Industries; Robert C. Sprague, Sprague Electric; Leslie F. Muter, Muter; W. G. Roby, Cinch Mfg.; J. H. Stackpole, Stackpole Carbon; Thomas A. White, Jensen Radio Mfg.; A. Blumenkranz, General Instrument; George Fraser, Astatic Microphone; Hugh H. Eby, Hugh H. Eby, Inc.; L. W. Howard, Peerless Electrical Products; Jerome J. Kahn, Standard Transformer; Harry E. Osmun, Centralab; Harry Ehle, International Resistance; and C. L. Walker, Utah Radio Products.

BROADCAST POWER. By an amendment to section 3.64 of its rules governing standard broadcast stations,



GENERAL ELECTRIC MYCALEX

is an electrical insulator possessing a combination of features not found in any other single material. G-E mycalex, because of its high dielectric strength and low power factor, is ideally suited for use as a high frequency insulator in radio equipment and for ignition assemblies in high altitude aircraft. Arcs occurring at high altitudes do not cause permanent conductive tracks.

Because intricate shapes may be molded with G-E mycalex with "molded-in inserts", because these parts are made to extremely close tolerances and because their dimensional stability is high, G-E mycalex is a superior material for assemblies which must stand up under severe operating conditions. Although G-E mycalex can be drilled, milled, and ground, these operations are seldom necessary due to the fact that parts can be molded to shape.

For further information write section N-253, One Plastics Ave., Pittsfield, Mass.

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GENERAL ELECTRIC
PD-253

Probably the most important single factor in modern warfare is complete, dependable communications. Dependable communications require a dependable power supply. Pincor is proud of its part in furnishing portable gasoline-driven and other electrical power supply units to the fighting front as well as to the home front.

Look to Pincor for your postwar needs in power plants, motors, converters and battery chargers.

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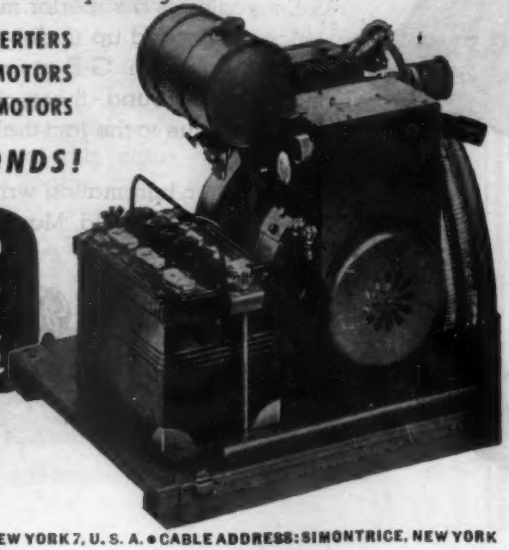

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FCC makes it possible for a station operating with different power day and night to get a license authorizing the use of alternate transmitters. Requirements are that both be located at one place and that both be substantially the same as to frequency stability, reliability of operation, radio harmonics and other spurious emissions, audio frequency range, and audio harmonic generation.

AUTOMATIC PHONOGRAPHS. The following individuals have been appointed by WPB to constitute the commercial automatic phonograph industry advisory committee: J. E. Broyles, Rudolph Wurlitzer; Robert Gabel, John Gabel Mfg.; Carl T. McKelvy, J. P. Seeburg; David C. Rockola, Rock-Ola Mfg.; E. E. Rullman, Automatic Instrument; and V. G. Wahlberg, Mill Industries.

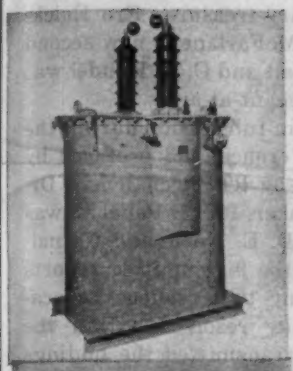
TUBES AND RADIO PARTS. Changing conditions have made it possible for the radio and radar division of WPB to revoke two limitation orders. Since distribution and production of several hundred types of tubes are now scheduled under M-293, their limitation by L-76 is no longer necessary. Replacement parts for home radios have been subject to L-293 which was designed for maximum conservation of materials without regard to the most efficient use of production facilities. Its removal will allow production of these components on the same lines that are running other parts.

APCO Conference

ACCENT ON the importance of retaining present police radio channels and providing for additional radio frequencies in the postwar period was made at the 11th annual national conference of Associated Police Communication Officers in a three-day session at Toledo, Ohio, during September.

Selection was made by the 300 members present of a large police radio committee to appear at the FCC allocations hearing in Washington in October.

Acclamatory re-election of the principal officers for 1945 included: president Frank W. Walker; first vice-president Ray S. Groenier; *Bulletin* editor Capt. J. M. Wherritt



Single phase, half wave rectifier plate transformer, 60 cycles, 220 volts primary, 110,000 volts secondary.

300 VA Filament transformer, single phase, 60 cycles, 6 secondary windings of 5 volts each; 3 secondary windings operating 40 KV above ground and 3 secondaries operating 20 KV above ground.

60 KVA, three phase, 60 cycles, 211 volts, Delta primary, 8900 / 6755 / 7800 / 13510 volts Wye secondary.

150 KVA Distribution transformer, single phase, 600 high voltage, 240/120 low voltage.

Fire!

REDUCE THE HAZARD WITH AMERTRAN ABESTOL IMMERSED TRANSFORMERS

Fireproof AmerTran Abestol Immersed Transformers reduce both the possibility and the extent of fire damage. That's why they earn lower insurance rates and permit vaultless indoor installation, with its convenience, flexibility and accessibility. To industry, AmerTran Abestol Immersed Transformers offer the advantages of load center installation: copper savings, finer voltage regulation, lower line losses and improved motor performance. If necessary, they may be mounted overhead because the chemically inert Abestol, which requires no maintenance, is sealed. In comparison to transformer oil, Abestol possesses higher insulating properties and similar heat transmission characteristics.

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This is not a balloon barrage. It is an actual photograph, highly magnified, of parasitic organisms (fungus growths), the control of which poses one of the toughest problems our armed forces have to contend with in keeping electrical and communication equipment in operation.

If your present contracts utilize electrical coil windings, and call for "tropicalization" or "anti-fungus" treatments, our 27 years of experience are at your service to provide proper coil design and treatment.

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and secretary-treasurer Ero Erickson. D. J. McFarlane is new second vice-president and C. H. Knudel was chosen sergeant-at-arms.

Meeting in full session during the APCO conference, and prefaced by an address by RTPB chairman Dr. R. G. W. Baker, RTPB Panel 13 was headed by D. E. Noble and formalized all of the 9 committee reports by approving the frequency allocations already resolved within the Panel and transmitted the findings to the Planning Board.

A police allocations sub-committee agreed to support an interspersed frequency allocations scheme in preference to a block system of assignments and emphasized the need of low-frequency police radio channels in mountainous regions of California and the east, in addition to the retention of essential point-to-point radiotelegraph and voice channels now in use.

Experimental Canadian FM

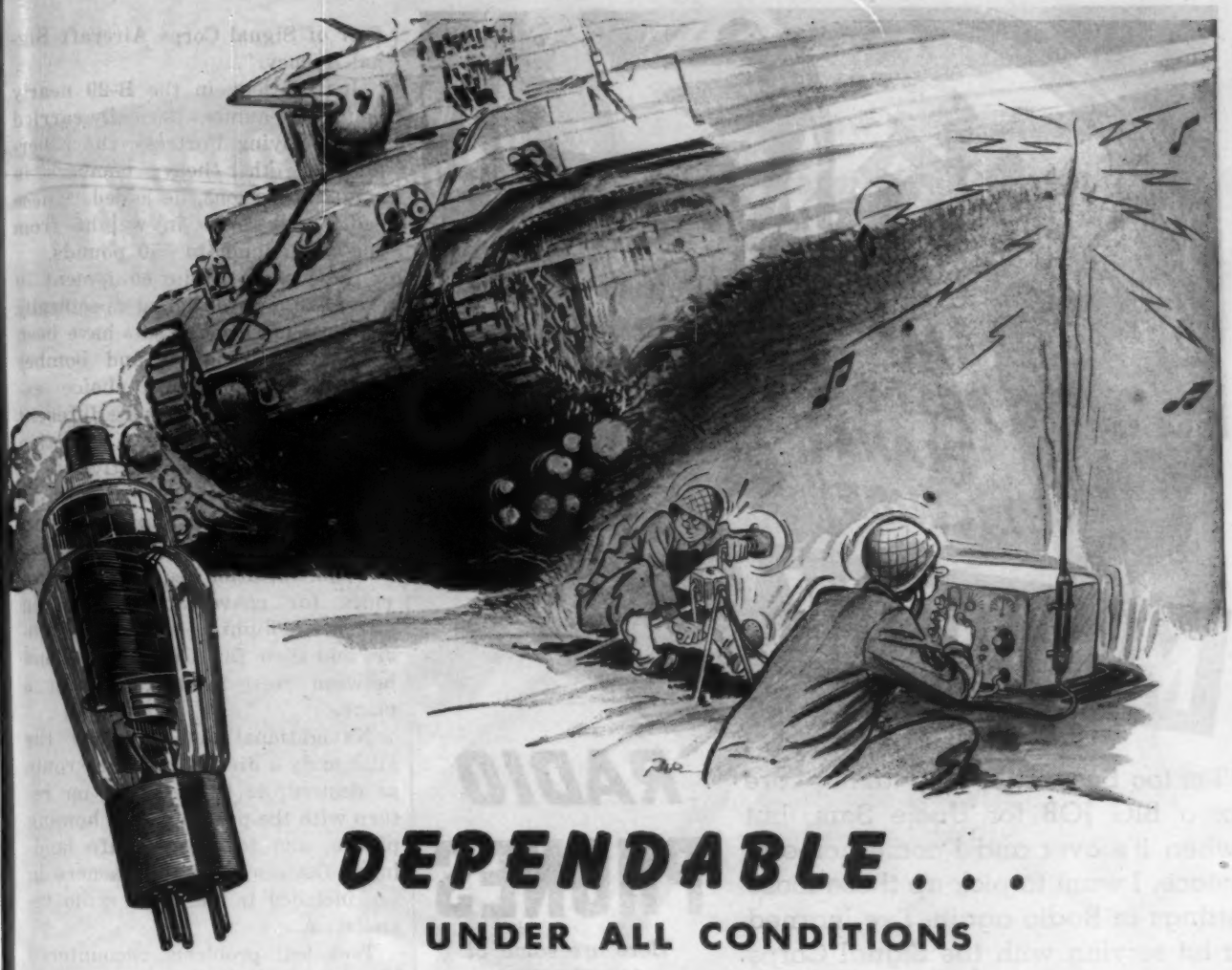
FOLLOWING UP EXPERIMENTS which had previously been made at Montreal, Canadian Broadcasting Corp. plans to establish an experimental f-m transmitter in that city. Funds will come from the $100,000 reserves of the Corporation, according to Dr. Augustin Frigon, assistant and acting general manager.

Electronics on the Super-Fortress

COMMUNICATION AND navigational aids have an outstanding importance to the AAF's 20th Air Force, operators of the B-29 Boeing Superfortress task force. Communications are under the direct command of Brigadier General Harold M. McClelland, air communications officer for the AAF.

When each of the Superfortresses takes off on bombing flights over Japan it carries approximately 2,000 lb of Signal Corps aircraft radio equipment.

Composed of many different radio sets and devices, all of which were either developed or improved in the Signal Corps' aircraft radio laboratory at Wright Field, the radio complement for this superbomber was the largest single installation job ever undertaken by the laboratory, according to Col. Hobart R. Yeager, commanding of-



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UNDER ALL CONDITIONS

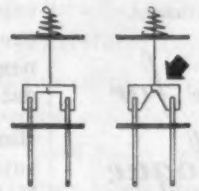
By concentrated abuse, the war has proved the relative merits of materials and construction in many kinds of equipment. This is particularly true in the case of Electronic Tubes.

The fact that TUNG-SOL Tubes have given long and efficient service in all kinds of electronic devices is no happy accident. It is the result of many years of intensive research . . . tests for performance in screen rooms by radio scientists . . . tests for ruggedness by engineers to find possible weaknesses . . . redesigning to make sure that tubes meet the most exacting requirements of use. For instance, in one particular transmitting type, the tendency of the filament wires to go out of alignment from vibration was a common shortcoming. This was remedied by a change in one simple construction feature as shown below.

Manufacturers and users of electronic devices may be assured that the sending, receiving and amplifying TUNG-SOL Tubes they buy for initial equipment and replacement are as uniform and as dependable as it is humanly possible to produce them. TUNG-SOL's engineering development staff is ready to work with you on your Electronic Tube requirements.

HOW TUNG-SOL FILAMENTS STAY IN ALIGNMENT

One method of holding the filament wire in tension was to hook the tension wire to a flat suspension bar. However, TUNG-SOL engineers found that vibration often caused the spring connection to shift along the bar, thus forcing the filament out of alignment. The improved suspension arch eliminated this possibility.



ARMY E NAVY

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ELECTRONIC TUBES

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ALSO MANUFACTURERS OF MINIATURE INCANDESCENT LAMPS, ALL-GLASS SEALED BEAM HEADLIGHT LAMPS AND CURRENT INTERMITTORS

"I'm too busy right now taking care of a BIG JOB for Uncle Sam, but when it's over and I come home to peace, I want to pick up those loose strings in Radio again. I've learned a lot serving with the Signal Corps and that experience will come in handy when I return to my job in radio communications. But there's one thing I'm going to insist on, and that's MURDOCK Radio Phones—I'm mighty fond of their clearness and light weight—and I want that same cushioned comfort later on. Yes, sir!"

For 40 years MURDOCK precision engineering has been devoted to making the keenest ears in Radio. In War and Peace, MURDOCK means crystal clear and dependable communications.

SUB-CONTRACTS ACCEPTED

Though most of our facilities are devoted to government work, we can make more Radio Phones and related parts for you on a sub-contract basis. We'll be glad to help you.

RADIO PHONES

Here are some of MURDOCK'S Exclusive Features:

1. CUSHIONED COMFORT for long listening.
2. VENTILATED for ease and coolness — prevents condensation.
3. SUPER-SENSITIVITY for clear and accurate reception.
4. STURDY, SOLID-BUILT by precision methods —close tolerances.
5. TWO-WAY ADJUSTMENT to control position.
6. CONCEALED TERMINALS—plus long cords for easy movement.

Write for Catalogue

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ficer of Signal Corps Aircraft Signal Agency.

Installations in the B-29 nearly double the number normally carried by the Flying Fortress, the Liberator, or other heavy bombers in actual operations, he added. These radio sets range in weight from one-half pound, to 550 pounds.

None of the radio equipment in the B-29 was designed specifically for it as most of the sets have been used in both fighter and bomber aircraft. Wherever a choice existed between two or more different sets of a similar type, a selection was made after exhaustive tests of the equipment to determine which would give maximum performance on long-range flights.

Communication equipment provides for conversations between aircraft in flight, between the bombers and their far-distant bases and between crew members within a plane.

Navigational devices allow the pilot to fly a direct or diverse route as desired, to locate bases on return with the precision of a homing pigeon, and to execute safe landings. Devices to guide rescuers in are included in the B-29 radio installation.

Technical problems encountered by Aircraft Radio Laboratory were numerous because of the great number of different types of radio equipment which had to be installed and made to operate without conflicting with or neutralizing each other.

PERSONNEL

L. J. Chatten, formerly assistant director, has been made director of the radio and radar division, WPB. He succeeds **Ray Ellis** who is returning to his post at General Motors Corp.

Head of research on electronic products at Littelfuse Inc., Chicago, Ill., is **Bernard F. McNamee,** previously in charge of the engineering department of Consolidated Engineering Co.

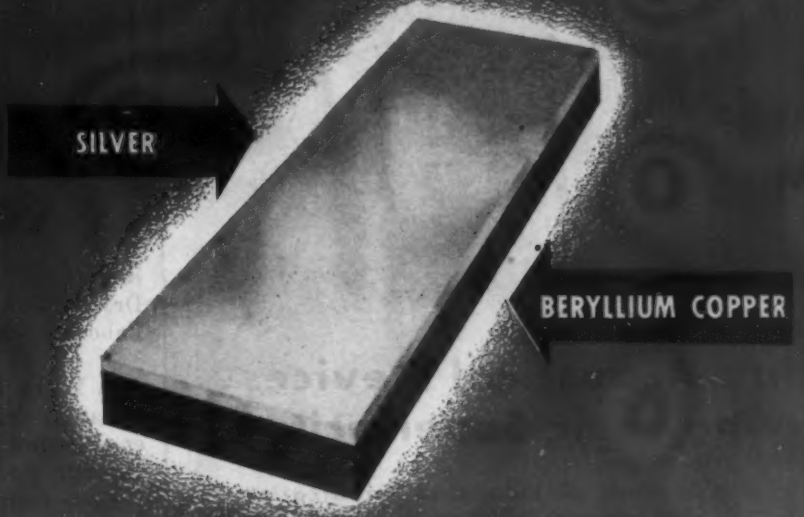
Harold Hadden, control and studio supervisor at WOR, New York, N. Y., is coordinating technical assignments and operations between that station and WABD on television productions.

At Philco Corp., Philadelphia, Pa.,

ANNOUNCING

The New General Plate Laminated Metal

"Silver on Beryllium Copper



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- **FOR TINY SWITCH BLADES TO HEAVY STRIPS**
- **FOR EXTRA CONDUCTIVITY**
- **SILVER CLAD (NOT ELECTROPLATE)**

First in the parade of new General Plate Metals for post-war use is the new laminated combination of *Silver on Beryllium Copper.*

Made by permanently bonding silver to beryllium copper, it gives you the extra conductivity of silver . . . so badly needed where only beryllium copper meets the requirement . . . plus the springiness of beryllium copper.

No matter whether your requirements call for tiny switch blades or heavy strips, General Plate laminated *Silver on Beryllium Copper* will provide better performance. It is available in combinations of silver on one side or both sides in any thickness—or centre-lay (silver between two layers of beryllium.)

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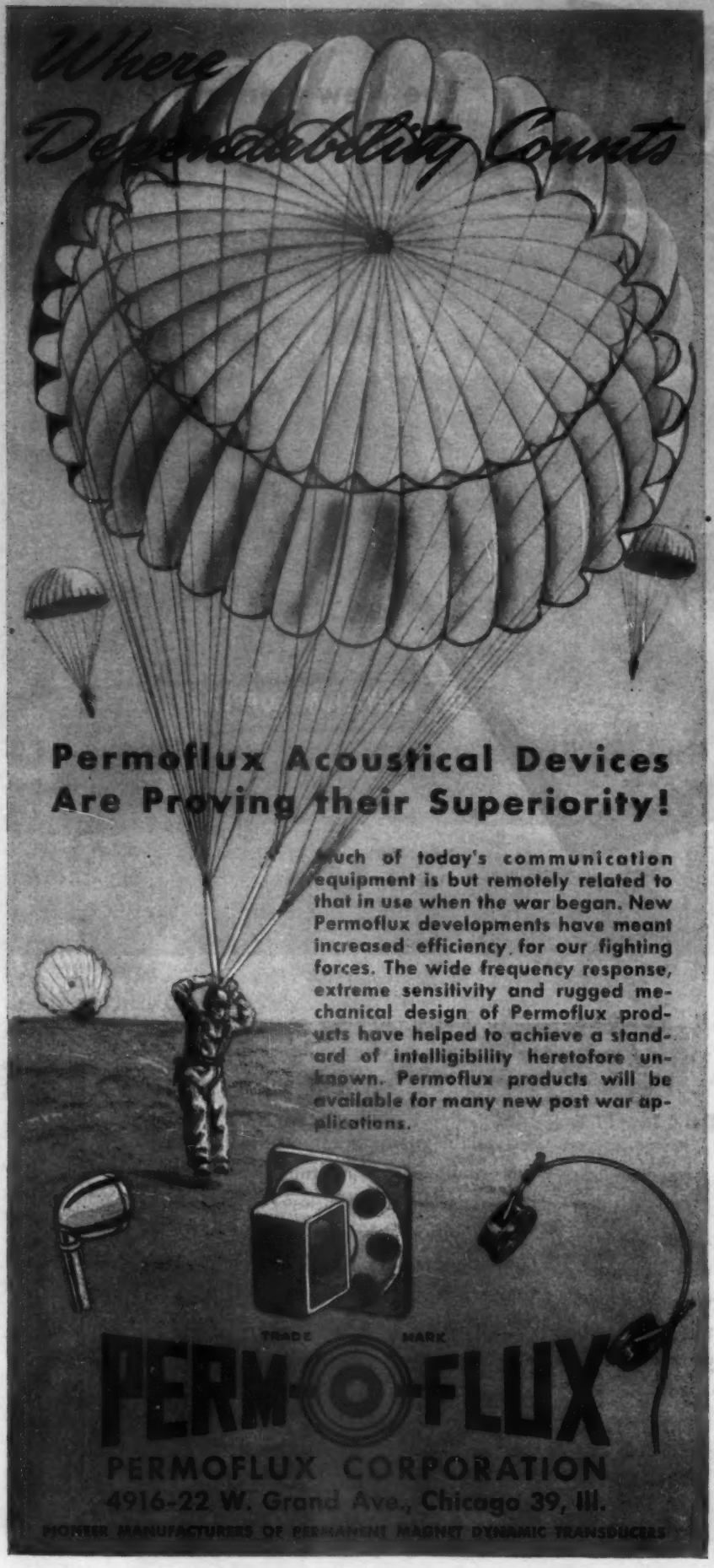
Where Dependability Counts
Permoflux Acoustical Devices Are Proving their Superiority!
Much of today's communication equipment is but remotely related to that in use when the war began. New Permoflux developments have meant increased efficiency for our fighting forces. The wide frequency response, extreme sensitivity and rugged mechanical design of Permoflux products have helped to achieve a standard of intelligibility heretofore unknown. Permoflux products will be available for many new post war applications.
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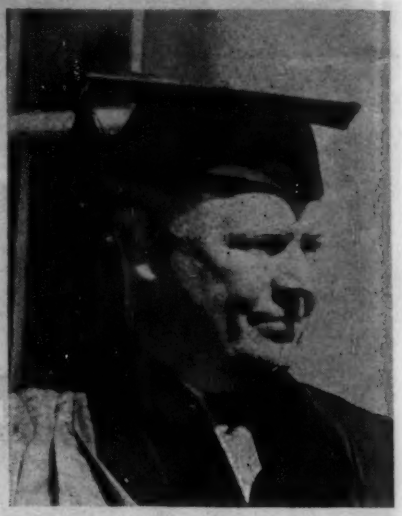
PERM-O-FLUX
PERMOFLUX CORPORATION
4916-22 W. Grand Ave., Chicago 39, Ill.
PIONEER MANUFACTURERS OF PERMANENT MAGNET DYNAMIC TRANSDUCERS

William Balderson goes from vice president in charge of the commercial division to take charge of operations and become a member of the executive committee.

Allen B. Du Mont has been made honorary doctor of engineering by



Rensselaer Polytechnic Institute. Dr. Du Mont is head of Du Mont Laboratories, Inc., Passaic, N. J.

C. W. La Pierre has been made assistant engineer of the general engineering laboratory at General Electric Co., Schenectady, N. Y. He was formerly in charge of the electro-mechanical section there.

John H. Miller has been made chief electrical engineer at Weston Electrical Instrument Corp., Newark, N. J. He was formerly assistant chief electrical engineer.

Philip F. Siling has been made engineer in charge of the frequency bureau of Radio Corp. of America. He was formerly assistant chief engineer in charge of broadcasting for FCC.

Frank J. Hajek has been made president of Taylor Tubes Inc., Chicago, Ill. He was formerly secretary-treasurer.

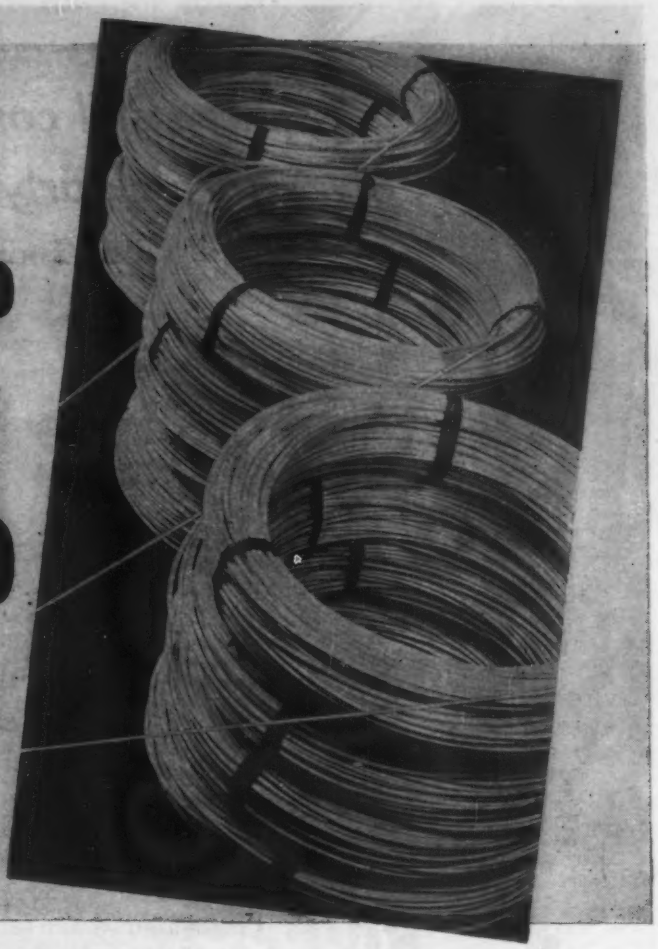
James C. Filmer has been made vice-president in charge of engineering at Taylor Tubes Inc., Chicago, Ill.

Dr. Lee de Forest has been active in the organization of a center for electronic research, a factory for the production of radio

WILCO NOW EQUIPPED

for large scale production of

JACKETED WIRE



WILCO wire, tubing and other products are used in various electronic applications for the Army and Navy. In response to the wartime demand for these various products, the H. A. Wilson Company has enlarged its plant, increased its manufacturing facilities, added essential new equipment and developed new products and techniques. Both present and future customers will find these new WILCO developments of great advantage.

The H. A. Wilson Company manufactures and is interested in receiving inquiries regarding the following typical products—

WILCO JACKETED WIRE

Silver (Fine, Sterling or Coin)
Silver Jacketed Copper
Silver Jacketed Invar
Silver Jacketed Brass
Silver Jacketed Steel
Gold Jacketed Silver (Fine, Sterling, Coin)
Gold Jacketed Brass or Bronze
Copper Jacketed Monel
Nickel Jacketed Copper

WILCO JACKETED TUBING

Silver Tubing (Fine, Sterling or Coin)
Gold Tubing (any Color or Karat)
Silver Jacketed Brass or Bronze (one or both sides)
Gold Jacketed Silver (one or both sides)
Gold Jacketed Brass or Bronze (one or both sides)

WILCO STRIP MATERIAL

Silver (Fine, Sterling or Coin) on Brass or Bronze (Inlay or Overlay)
Gold on Silver (any Karat on Fine, Sterling or Coin)
Gold on Brass or Bronze

Other WILCO products include Electrical *Contacts*—

Silver, Platinum, Tungsten, Alloys, Powder Metal. *Thermostatic Bimetal* (High and Low Temperature with new high temperature deflection rates.) *Precious Metal Collector Rings*—For Rotating controls. *Silver Clad Steel. Rolled Gold Plate. Special Materials.*

Let us analyze your problems.

THE H. A. WILSON COMPANY

105 Chestnut Street, Newark 5, N. J.

Branches: Detroit • Chicago

"You're still coming thru clearly!"

IN NEW CALEDONIA *Telex Receivers were given an assignment where super-sensitivity was vital—the clear reception of enemy reconnaissance information.*

Photograph Signal Corps, U.S. Army

TELEX
Experience Offers:

Magnetic Receivers:

Cu. Vol.—Approx. 0.3 cu. in.

Impedance—Up to 5000 ohms.

Sensitivity—18 dynes/sq. cm. for 10 microwatt input.

Construction—Rugged and stable, using only finest materials, precisely machined—no diaphragm spacing washers in Telex receivers.

Transformers and Chokes:

Cu. Vol.—Down to .15 cu. in.

Core Material—High permeability steel alloys.

Windings—To your speci. (Limit of six outside leads on smallest cores.)

GATHERING enemy information often calls for trips inside enemy lines. When the messages are dispatched Telex Magnetic Receivers deliver them with distinct clearness.

The engineers of Telex stressed super-sensitivity and high-fidelity performance in perfecting these tiny receivers for the U. S. Army Signal Corps. An unusual ruggedness prepares them to meet world-wide conditions. That's why it's first in dependability if it's made by Telex.

Let Telex engineers help you to solve your present and near future electronic development problems. In creating the first wearable Electronic Hearing Aid and in serving the U.S. Army Signal Corps they are prepared to put ingenuity and experience to work for you. Write to us.

ELECTRONICS PRODUCTS DIVISION

TELEX

PRODUCTS COMPANY

TELEX PARK • MINNEAPOLIS • MINNESOTA

and television equipment, and a commercial television station, all at Mexico, D. F., Mexico.

Maurice H. Hobbs has been made manager of the engineering department in the switchgear and control division at Westinghouse Electric & Mfg. Co.

William Vassar has been made administrative assistant to the vice-president in charge of engineering and production at Emerson Radio & Phonograph Corp., New York, N. Y. He was formerly an executive engineer at Crosley Corp.

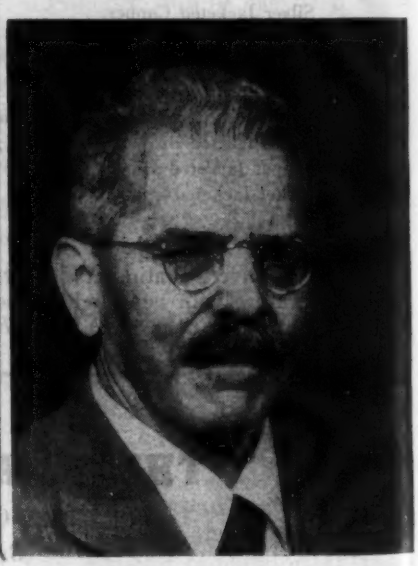
Frank X Lamb has been made assistant chief electrical engineer at Weston Electrical Instrument Corp., Newark, N. J. He was formerly a project engineer.

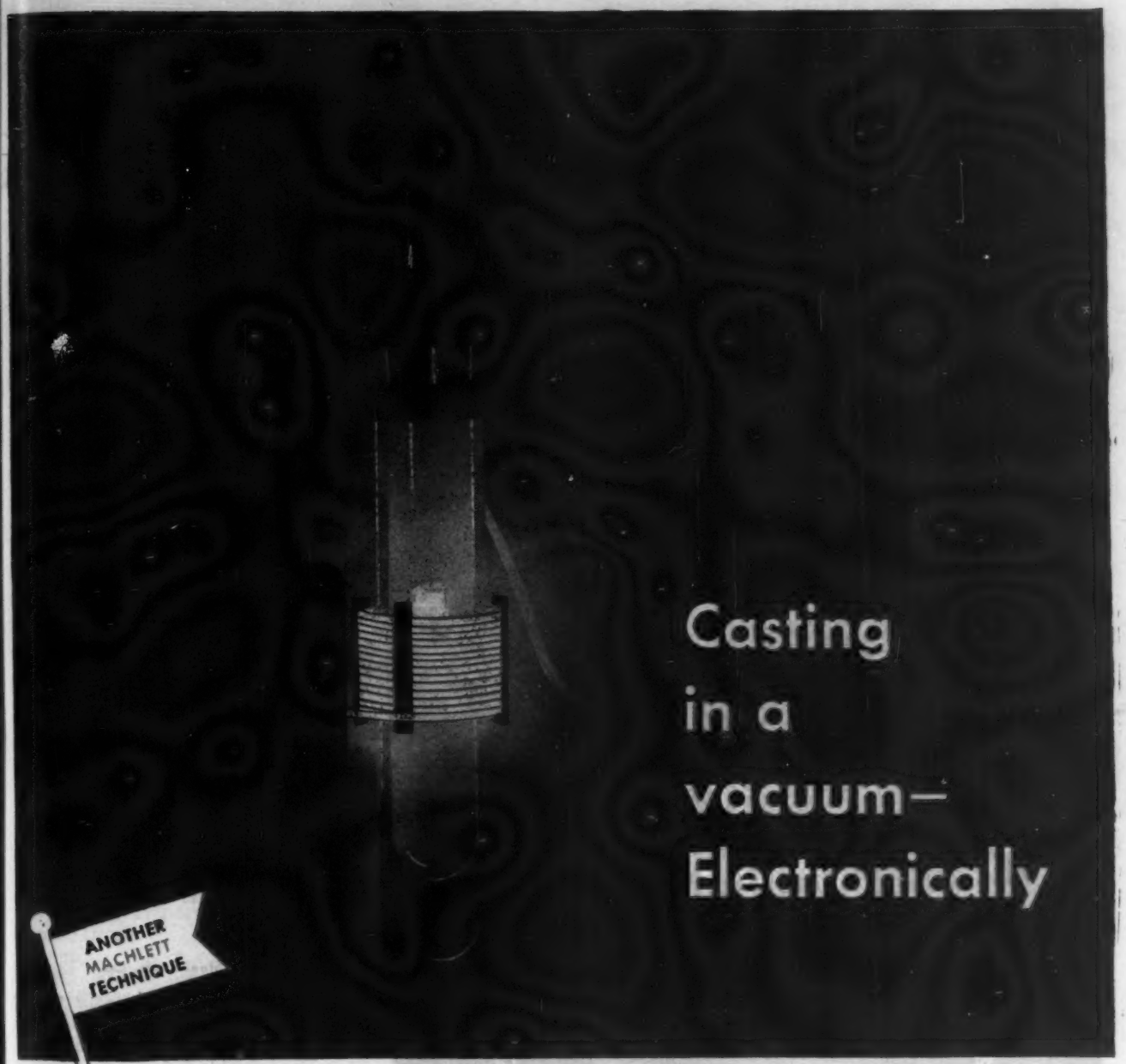
Charles F. Kettering has been made a member of the subcommittee on applied cyclotronics of the post-war program committee of the State of Ohio. He is head of General Motors Corp. research.

Wendel C. Fowler has been made president of the Fort Worth Electronics Club, Fort Worth, Tex.

Roy Siren has been made engineer in charge at Milwaukee Industrial Designers, Milwaukee, Wis. He was formerly with Nordberg Mfg. Co.

Karl M. Lederer has been made assistant director of research at Weston Electrical Instrument Corp., Newark, N. J. He was formerly assistant chief engineer.

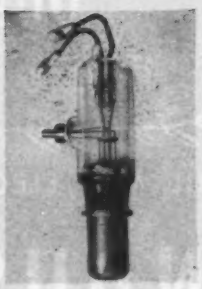




One of the many vital processes that give Machlett vacuum tubes their remarkable quality is a novel method of casting electrodes in a vacuum. Complex parts of high-frequency oscillators, as well as X-ray tube anodes, are made by this unusual technique. Purified copper rod is placed over a mould in a graphite crucible, and the whole enclosed within a double-walled water-cooled quartz-silicon tube, which is encircled by a high-frequency coil. A vacuum of about 10^{-5} mm. of mercury is maintained.

When the current is turned on, the metal melts and flows into the mould. Cooling is precisely controlled by adjusting the position of the heating coil, so that crystals form longitudinally, for maximum heat transfer under operating conditions.

This method accomplishes a number of things, quickly and simply. No gases can be occluded in the metal to shorten tube life by reducing the vacuum. Oxides cannot form. There are no "pipes" in a casting thus poured. Dimensions can be held to about 1/10,000th of an inch—and accurate dimensions are as important as metal purity in protecting transmitting tube performance, both assuring the maximum designed performance and long life. Techniques such as this make possible the production of the tube shown above . . . Machlett Laboratories, Inc., Springdale, Connecticut.



ML-846—An U. H. F. transmitting tube for television and F. M. and short wave broadcasting.

MACHLETT

X-RAY TUBES SINCE 1898

TODAY THEIR LARGEST MAKER

THE CONDENSER LINE OF UNSURPASSED QUALITY

PAPER, OIL AND ELECTROLYTIC CONDENSERS

INDUSTRIAL
CONDENSER CORPORATION
1725 W. NORTH AVE., CHICAGO, U. S. A.

DISTRICT OFFICES IN PRINCIPAL CITIES
QUICK DELIVERY FROM DISTRIBUTOR'S STOCKS

At Westinghouse Electric & Mfg. Co. **R. T. Muench** is made manager of the x-ray products department. Since 1942 he has been manager of the Detroit x-ray office.

I. Walter Wyckoff has been made president of Electronics Manufacturers Association, New York, N. Y. He is connected with Pilot Radio Corp.

AWARDS

ON THE SECOND ANNIVERSARY of the presentation of the first Army-Navy "E" Awards, the War Department announces that the award has been granted to 3,097 plants. Based on various statistical reports, it has been estimated that approximately 3½ percent of the Nation's eligible plants have received the award.

Adel Precision Products Corp.
Huntington Precision Prod. Div.
Huntington, W. Va.

Aerovox Corporation
New Bedford, Mass.

Eagle Signal Corp.
Moline, Ill.

Electrical Research Labs., Inc.
Evanston, Ill.

Electro-Voice Mfg. Co., Inc.
South Bend, Ind.

General Electric Co.
Transmitter Div.
Syracuse, N. Y.

Hytron Corp.
Salem, Mass.

The Indiana Steel Prods. Co.
Valparaiso, Ind.

Litton Engineering Labs.
Redwood City, Calif.

Sonotone Corporation
White Plains, N. Y.

Union Aircraft Products Corp.
New York, N. Y.

CHIEF SIGNAL OFFICER'S CERTIFICATES OF APPRECIATION

These awards are testimonials to the contribution of individuals and organizations not eligible for Army-Navy recognition.

Louis H. Lamotte
International Business Machines Corp.

Chester W. Latimer
Vice-Pres. and Chief Engineer
RCA Communications

Samuel Ruben
New Rochelle, N. Y.

George E. Smith
Vice-President
Crosley Corp.

William A. Winterbottom
Vice-Pres. and General Mgr.
RCA Communications, Inc.

JUST AROUND THE CORNER

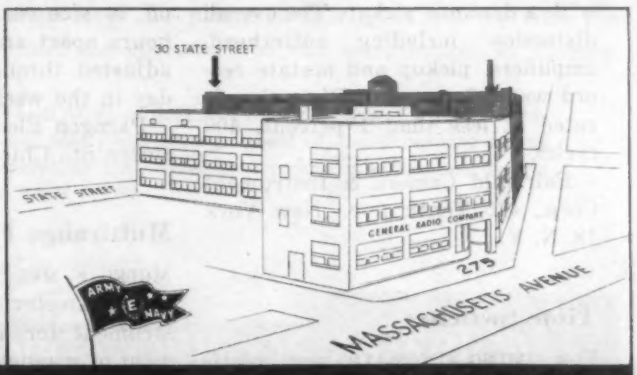
● LATELY, persons corresponding with us have noted a new address . . . 275 Massachusetts Avenue. We've moved our engineering and general business offices into a remodeled building at this location. It's just around the corner from 30 State Street, which is still ours, and which is now devoted exclusively to manufacturing.

For a long time we have felt the need for rearranging our space; for one thing we have been badly cramped in the shop; and our engineering department has been spread over several floors and mixed up with many other activities.

The new building, which is connected by ramps on two floors with the older one, provides about 30 per cent more manufacturing space, and allows all of the engineering department to be on one floor.

Under pressure of the war we have expanded our output in several ways. We have let out the manufacture of several instruments to subcontractors; we have turned over the designs, drawings and models of several instruments to other manufacturers for their exclusive use; we have rented considerable extra space in two outside buildings, in one of which we have contracted for a large number of war-time workers under our own foremen.

After the war when the armed guards have left us, we hope that you will come to see our new laboratories and offices. In the meantime we continue to devote our energies to filling war orders for electronic laboratory test equipment.



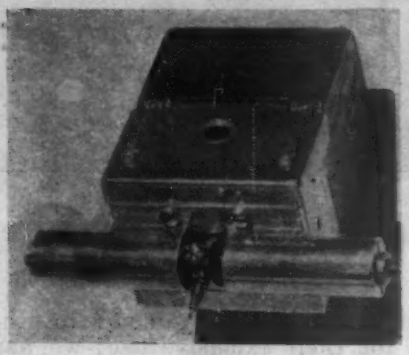
MADE ONLY BY **GENERAL RADIO COMPANY** Cambridge 39, Mass.
NEW YORK
CHICAGO
LOS ANGELES

NEW PRODUCTS

Month after month, manufacturers develop new materials, new components, new assemblies, new measuring equipment; issue new technical bulletins, and new catalogs

Magnetic Cutterhead

UNIT NO. 541 MAGNETIC cutterhead is for use in standard lateral recordings and is designed to give wider, distortion-free response. It is used as standard equipment on portable recorders made by this manufacturer. Frequency response is ±2 db, 30–8,000 cycles; impedance, 500

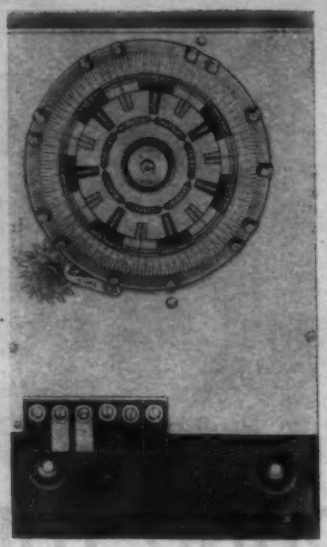


ohms; audio power required 0.6 watts (+20 db); size stylus accommodated, ⅛ in. long, 0.0062 in. diameter. The manufacturer states that a recording of a 400-cycle note was made at a recording level of +18 db (reference 0.006 watts) to produce a stylus velocity of 2.5 in. per second. Playback was made with a dynamic pickup. The overall distortion including cutterhead, amplifiers, pickup and acetate record was 1.7 percent. Distortion is rated at less than 1 percent, 400 cycles.

Fairchild Camera & Instrument Corp., 475 Tenth Ave., New York 18, N. Y.

Time Switches

FOR TIMING AUTOMATIC heat, ventilating, lighting, pumping or flushing operations there is available the Paragon 700 Series which is a 7-day calendar dial time switch. These



switches are equipped with 6-in. calendar dials which make one complete revolution every 7 days. Dial trippers can be independently set for different daily on and off schedules. Settings can be made in advance for an entire week. Any day or days operations may be omitted entirely on a pre-set program. Days, hours and half-hours, day and nights are distinctly separated from each other. Operations from on-to-off, or vice versa, can be set three hours apart and can be separately adjusted throughout each 24-hour day in the week.

Paragon Electric Co., 39 W. Van Buren St., Chicago 5, Ill.

Multirange Fluxmeter

MODEL F MULTIRANGE, direct-reading, fluxmeter is an improved instrument for use in the measurement of magnetic circuit conditions and associated tests. Its scale length is 5.2 in., accuracy ½ percent. The range is 5 lines per sq. cm. to 30,000,000 lines per sq. cm. The instrument requires no leveling. Improvements of Model F include search coil resistance up to 15 ohms; increased sensitivity of the basic movement, new method of introducing the current into the moving coil, four additional ranges of lower sensitivity, and method of calibration. The instrument is thoroughly described and illustrated in an 8-page booklet. The booklet's back cover is devoted to the subject of the "Theory of Fluxmeter."

Sensitive Research Instrument Co., 9 Elm Ave., Mount Vernon, N. Y.

Time Meter

TYPE R-161 "TIMETER" is a quick-reset, electrically-operated measuring instrument which automatically registers the total operating hours of any electrical device or motor-driven machine. The unit registers by tenths of hours up to 999.9, and then repeats. It is rated 100-125 v, 60 cycles, 2 watts, a.c., and its dimensions are 3 5/16 in. wide, 3⅜ in.

high and 2⅜ in. deep. A resistor or transformer is supplied for circuits of higher voltage. Resetting is accomplished by an external knob located under a protective cap. The instrument is available with or without reset features. It is surface mounted.

National Instrument Co., 246 Walnut St., Newtonville 60, Mass.

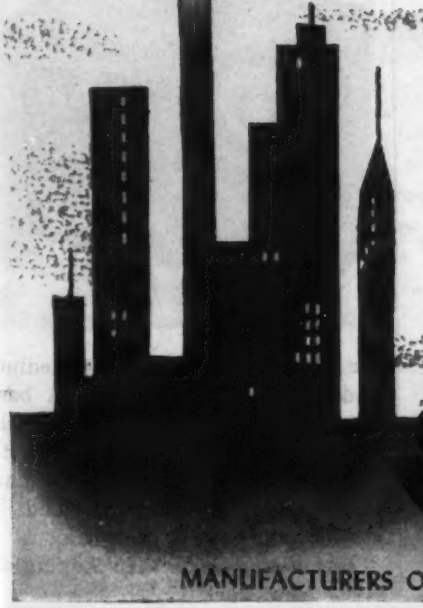
SYMBOL OF ACHIEVEMENT IN AMERICAN INDUSTRY

TO THE ELECTRONIC CORPORATION OF AMERICA, the Army-Navy "E" award has always symbolized all that is good in American industry. To us, it means that labor and management are cooperating for the welfare of our country. It means that Americans of different races and religions are working together in harmony. It means that an abundance of creative ideas are thoroughly and speedily carried out. Because we of ECA believe in and practice the ideals for which this award stands, we are extremely proud to announce that we have received the coveted Army-Navy "E".

To the engineers who design our precision electronic equipment and to the men and women who build it... to the members of our two CIO unions and to the members of management—all of whom have given their best during these crucial war years, the Labor-Management Committee of the Electronic Corporation of America extends heartiest congratulations. To our suppliers and the personnel of the military forces, who have so ably and diligently assisted us, we offer our sincere thanks.

We shall continue to keep the quantity and quality of our war production consistently high. And when the war exists only in the pages of history, we shall serve the people of this great country with the same devotion that has characterized our contribution to Victory.

Just Published! "A PLAN FOR AMERICA AT PEACE." A sound workable, realistic plan for a postwar world of abundance and lasting peace, prepared by the Electronic Corporation of America. WRITE FOR YOUR FREE COPY.



RCA

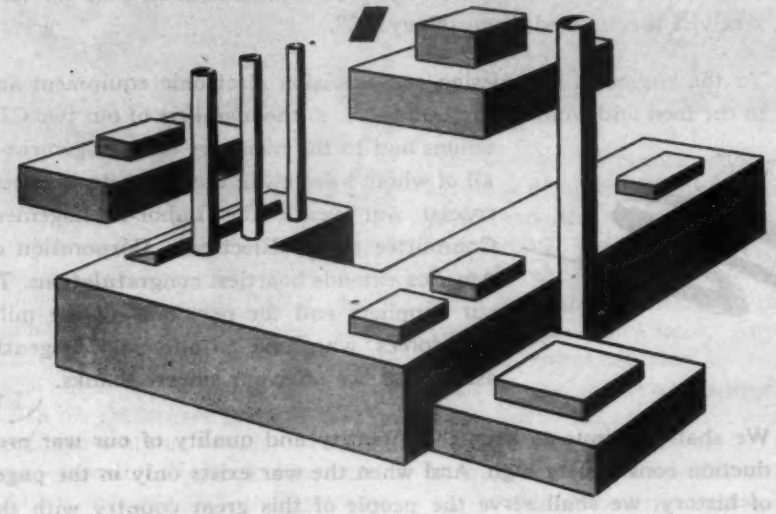
ELECTRONIC CORP. OF AMERICA

45 WEST 18th STREET • NEW YORK 11, N.Y. WATKINS 9-1870

MANUFACTURERS OF E C A . . . *the Radio Man's Radio*

the degree

to which your communications problems are solved may determine the degree of your postwar business success.



WRITE NOW FOR "CRYSTIONICS" INFORMATION

VALPEY

Crystal Corp.

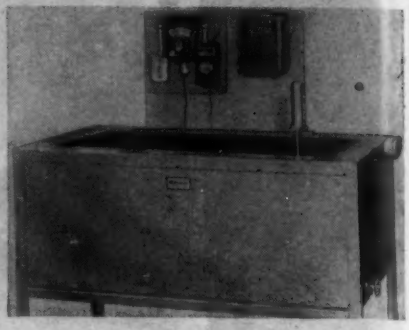
CRAFTSMANSHIP IN CRYSTALS SINCE 1921

HOLLISTON, MASSACHUSETTS

©1944

Wax Dipping-Baths

NEW AND IMPROVED electrically-heated and automatically-controlled wax dipping-baths are available which permit fast, efficient and economical wax-coating of coils, resistors, capacitors, panels and other

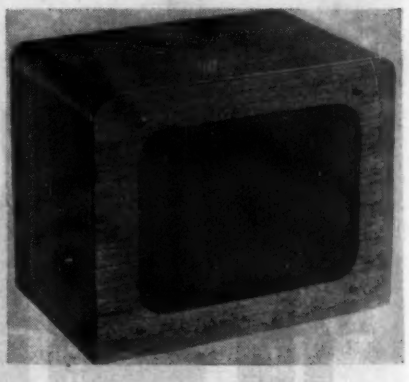


electrical parts. The units may also be used to wax-coat packages to guard against moisture absorption. Bath temperatures can be adjusted from 100 to 550 deg F. The baths are built to order.

Barnstead Still & Sterilizer Co., Forest Hills, Boston, Mass.

Sound Reproducer

MODEL NO. HF-6 is a new baffle-type reproducer unit which provides duo-directional high fidelity reproduction of both voice and music for plant broadcasting. The speaker is a 6-in. permanent magnet type with a 6-ohm voice coil. It delivers from 4 to 6 watts of output power, and is especially adaptable

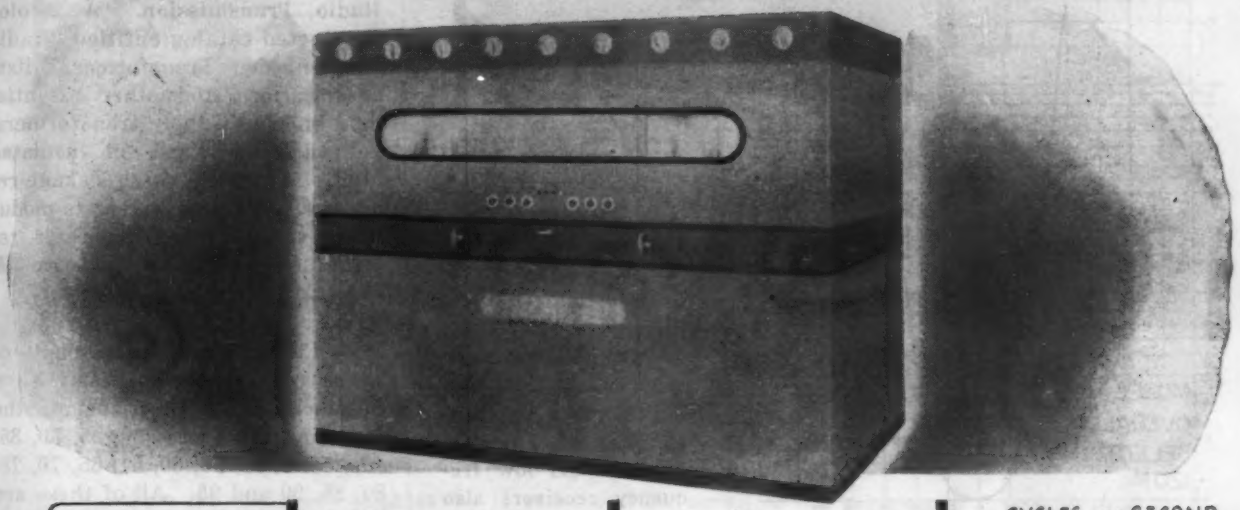


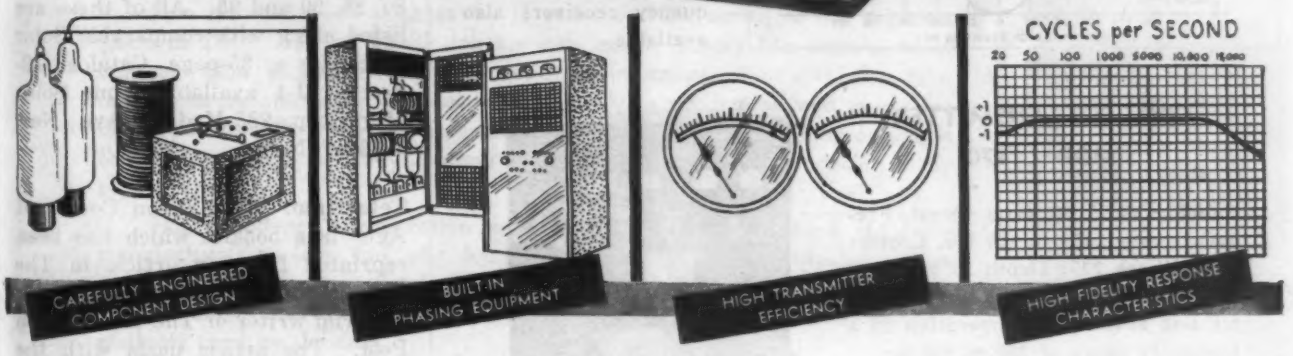
for wide-angle coverage of medium and low noise level areas. A bass compensation circuit progressively increases the bass response with each decrease of volume. The unit measures 9 x 10½ x 6½ in. and is suitable for desk or wall use.

Executone Corp., 415 Lexington Ave., New York 17, N. Y.

From GATES Engineering Laboratories—A Preview of New Transmitter Designing for the Post-War Radio Industry

Gates "BC-10"
5-10 KW BROADCAST TRANSMITTER





Here is one of the new things to come from Gates! Our engineers have already developed and approved engineering designs for this transmitter to be produced as quickly as the demands by the military on Gates' production no longer exist. The "BC-10" may be used for either 5,000 or 10,000 watt carrier. It is high level modulated and will be available complete with built-in phasing equipment.

May We Send You Details Regarding the Gates Priority System for Prompt Post-war Delivery

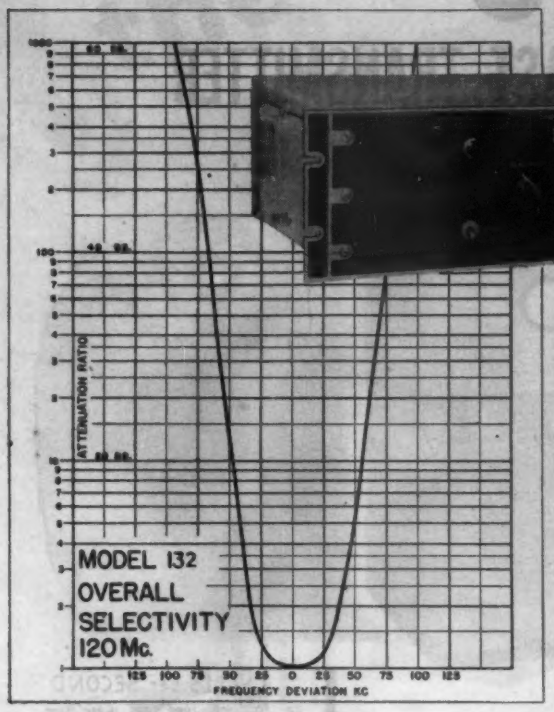
(Wartime restrictions do not allow the sale of new broadcasting equipment without priority; therefore, this equipment is presented merely to acquaint you with Gates' developments.)

Gates
RADIO and Supply CO.
QUINCY, ILLINOIS, U.S.A.

MANUFACTURERS OF RADIO BROADCAST TRANSMITTERS, SPEECH EQUIPMENT, RECORDING APPARATUS AND ALLIED EQUIPMENT IN THE ELECTRONICS FIELD

Best Performance in VHF

For Airlines — Airport Traffic Control
Police and Fire Departments



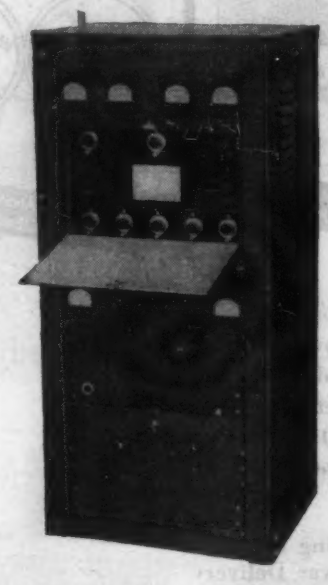
COMCO RECEIVER
MODEL 132

Compact VHF crystal controlled, fixed frequency, superheterodyne. Single channel reception; 5¼-inch relay rack panel mounting. 12 tubes. Frequency range 100 to 156 Mc. Medium and low frequency receivers also available.

COMCO TRANSMITTER
MODEL 170

Reliable VHF, 50 watts output. Frequency range 100 to 150 Mc. Cabinet size: Width 23"; Depth 18"; Height 48". Comco Model 127AA Transmitter also available for operation on a frequency range of 200 to 550 kc.

Comco Engineers have pioneered in the development of VHF equipment ... designed for ease of installation and maintenance ... ruggedly constructed to withstand varied climatic conditions and long service ... test-proved through three years of war. Write for complete details.



COMMUNICATIONS COMPANY, Inc.

Manufacturers of Radio and Electronic Equipment

CORAL GABLES — COMCO — 34, FLORIDA

Literature

Permanent Magnet Manual. "Permanent Magnets for Industry" is the title of an 8-page booklet which contains information on the design, production and use of modern magnets. Contents of the booklet include such subjects as magnet materials, resistance comparisons, physical and magnetic properties, demagnetization and energy curves, fabrication, design and testing. Arnold Engineering Co., 147 E. Ontario St., Chicago 11, Ill.

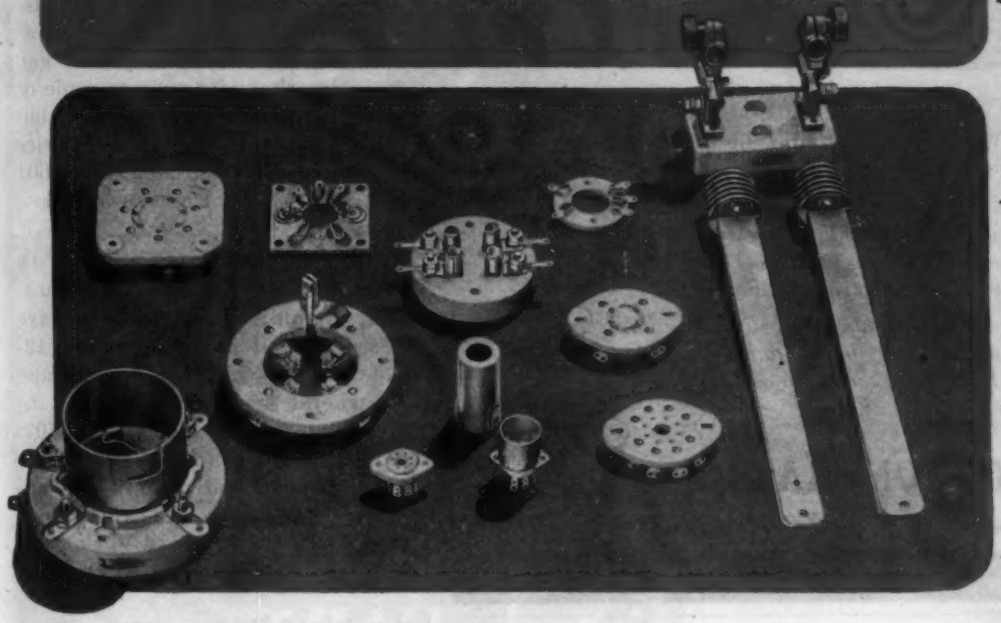
Radio Transmission. A 2-color illustrated catalog entitled "Radio Transmission Transformers" lists specifications and other essential data on plate supply transformers, both air-cooled and oil insulated types; filament, high-leakage-reactance, interstage, and plate modulation transformers, and filter reactors. The Acme Electric & Mfg. Co., Cuba, N. Y.

Mica Capacitors. Mica capacitors which are built to joint Army-Navy Specification JAN-C-5 include the following CM types: 20, 25, 30, 35, 40, 45, 50, 55, 56, 60, 61, 65, 70, 75, 80, 85, 90 and 95. All of these are listed along with comparable Solar types in a 35-page Catalog 12-Section J-1 available from Solar Mfg. Corp., 285 Madison Ave., New York 17, N. Y.

Television. "Television Comes of Age" is a booklet which has been reprinted from an article in The Nation, written by Alan Barth, an editorial writer of The Washington Post. The article deals with the post-war prospects for television pictures. It is available from The Columbia Broadcasting System, 485 Madison Ave., New York 22, N. Y.

Temperature Control Units. A recent issue of GR Experimenter contains an article "Notes on the Design of Temperature Control Units." These notes deal with a type of temperature control unit often used to control the temperature of a quartz bar or plate, for use as a frequency standard or frequency monitor. General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

Sockets FOR ALL TRANSMITTING TUBES



ANTENNAS

CONDENSERS

TUBE SOCKETS

PLUGS & JACKS

INSULATORS

INDUCTORS

BROADCAST EQUIPMENT

CONCENTRIC LINE

Fom the miniatures (such as the IT series or 9000 series) to the big ones (such as 204A, 833 or 889R) Johnson can usually supply the sockets. Most Johnson tube sockets have been designed in cooperation with the tube manufacturers and many of them were actually in production and ready for delivery before the tube was announced. This explains why the Johnson line is the most complete and why Johnson is the only manufacturer producing many of the types.

This confidence, cooperation and assistance on the part of the tube manufacturers explains too, why Johnson's mechanical and electrical design is superior. Both the Army and the Navy have recognized this superiority in Johnson wafer sockets for example, by specifying both the ceramic and the contacts used by Johnson.

Quantity production and economical manufacturing procedures make Johnson the best buy on the socket market — in fact the price is usually less than that of poorly designed imitations.

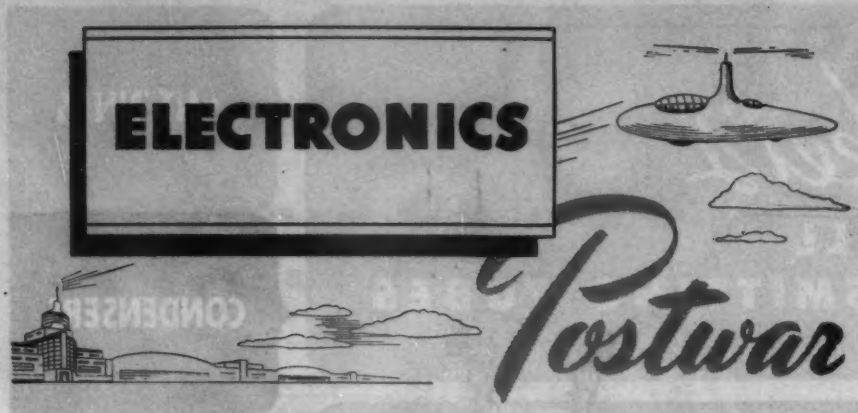
On that new socket requirement, investigate Johnson.

Write for Catalog 968D

JOHNSON

a famous name in Radio

E. F. JOHNSON CO.
Waseca, Minnesota



IN PEACETIME, Boonton Radio direct reading instruments were standard equipment for the Electronic Laboratory.

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This *New Jig Speeds* Your Radio Assembly

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Technical Monograph. "Loud Speaker Frequency Response Measurements" is the first publication of a series of technical monographs to help the amateur and the professional in the field of acoustics. Each publication will be devoted to one important aspect of the science of sound as applied to loud speakers. The first booklet (available for 25c) explains how one can use measured frequency response as essential data in development and design work, and describes some of the equipment and methods that may be used. Technical Service Dept., Jensen Radio Mfg. Co., 6601 S. Laramie Ave., Chicago 38, Ill.

Altitude Chambers. Altitude chambers for controlled temperature, humidity and pressure are described and illustrated in a 12-page booklet which contains a page of general specifications, plus information about Models AC-107, ACR-262, AC-36, 2000V, ACR-20, AC-8. Parts, instruments and accessories are also illustrated and described. Kold-Hold Mfg. Co., 424 N. Grand Ave., Lansing, Mich.

R-F Coils and Assemblies. This manufacturer makes coils for every application in the r-f spectrum, including radar and television, and has issued a 4-page bulletin entitled "Radio Frequency Coils and Associated Assemblies" as introductory literature. Stanwick Winding Co., Newburgh, N. Y.

General Products Catalog. Variable capacitor, plugs, jacks, inductors, chokes, terminals, tube sockets, couplings, antenna equipment and r-f insulators are all illustrated and described in Catalog No. 968 available from E. F. Johnson Co., Waseca, Minn. Another booklet, available from this manufacturer, is entitled "Johnson..In War and Peace" and it also illustrates and describes the types of products listed above, plus the particular catalogs which are available on these products.

Facsimile. This 12-page booklet is designed to bring about a better understanding of facsimile and its possibilities. The booklet contains actual reproductions as reproduced from receiver copy. Radio Station WELD, Columbus, Ohio.

SMALL!

The G-E Switchette

Don't handicap your important designs for lack of a SMALL electric switch

● Here's an inside view of the tiny, versatile G-E Switchette, enlarged to show you the double-break contact construction, which makes possible many ingenious wiring arrangements to solve tricky circuit problems. This is a standard form for controlling one normally open and one normally closed circuit. Variations of this arrangement are available to provide control of a single circuit, either normally open or normally closed. Other modifications include a form for simultaneously opening two circuits and closing one, or vice versa; also single-break forms for more sensitive operation.

BECAUSE of its unusually small size and light weight, its lightning-fast snap action, and its long life, the G-E Switchette is becoming more and more popular with designers for circuit control where space is at a premium.

Switchettes are available in ratings up to 10 amperes at 24 volts d-c (230 volts a-c), are provided with solder-lug terminals for wiring. They meet government specifications covering corrosion and vibration resistance, and operate at altitudes up to 50,000 feet and in ambient temperatures from 200 F to −70 F.

More than 200 modifications have already been developed to meet special circuit requirements and to fit into special mechanical arrangements. Dimensions, operating characteristics, and ordering directions for standard Switchettes and many typical modifications are given in our new catalog, No. GEA-3818C. For your copy, mail the coupon. If you don't find the forms you need in the catalog, our engineers will be glad to work with you in adapting Switchettes to meet your requirements.

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GENERAL ELECTRIC COMPANY, SECTION C676-141
SCHENECTADY 5, NEW YORK

Please send me Bulletin GEA-3818C giving dimensions, ratings, and operating characteristics of Switchettes

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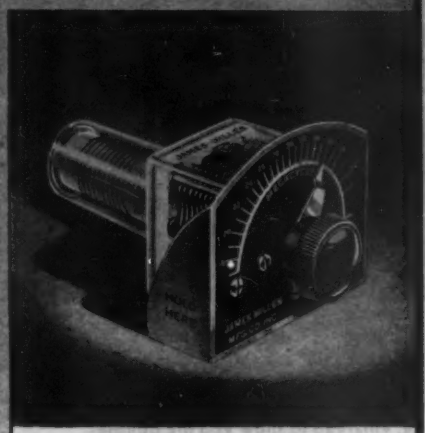
Switches. Catalog MC 448 is designed to simplify the selection of this manufacturer's multi-circuit switches for simultaneous operation of independent or interconnected electrical circuits. Twenty standard contactors are listed. Metallic Arts Co., 243 Broadway, Cambridge 39, Mass.

Tubes. The "1944–1945 Catalog and Manual" contains full information on all tubes manufactured by this firm, as well as some of the new tubes developed for war uses. Sixteen pages are devoted to tube characteristics. Another section is devoted to pertinent technical information on transmitters and transmitter tubes. The catalog is available, without charge, at local distributors, or may be obtained at a cost of 25¢ from Taylor Tubes, Inc., 2312 Wabansia Ave., Chicago, Ill.

Frequency Modulation Bulletin. This is the name of a bulletin which is published as source information on fm. Volume 1, No. 4 contains an article entitled "FM for 100,000,000 Americans" which states that more than 150 of the 210 applications for

Designed for Application



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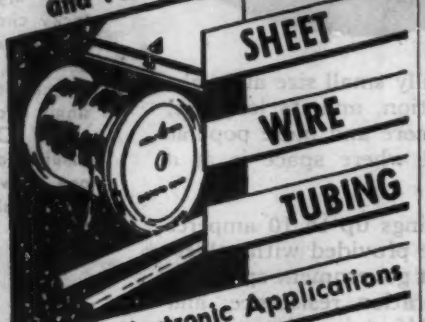

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Write for list of Products. Discussion of technical problems invited . . . .

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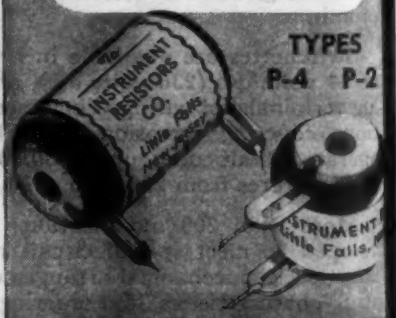
Type P-2 and P-4, illustrated, emphasize the low-cost factor inherent in all custom-designed, high-accuracy IN-RES-CO resistors. Type P-2 has a maximum resistance of 500,000 ohms, standard tolerance of ½%, ½ watt rating and measures 9/16" long by 9/16" in diameter. Type P-4, also non-inductive, has a maximum resistance of 1 megohm, measures 1" long by 9/16" in diameter, and has 1 watt rating.

Especially suited for precision apparatus and equipment applications, these types are representative of the all-inclusive IN-RES-CO wirewound resistor line. Here, engineering ingenuity—plus exclusive manufacturing techniques — can mean substantially lowered costs in post-war plannings.

A note on your company letterhead will bring your copy of the new IN-RES-CO catalog; no obligation.



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Illustrated are nine small components of an Ordnance assembly which Wadsworth furnishes in great numbers. The production of these pieces, which are held to very close tolerances, brings a score of special Wadsworth facilities into play.

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fm broadcast stations now in the hands of the FCC have been filed since the first of the year. The article further states that a comparison of requests for new broadcast services reveals that fm has maintained a 3-to-1 ratio over standard broadcast applications and a 3½-to-1 ratio over television applications. Three pages of this 4-page bulletin are devoted to a geographic listing showing frequencies, coverage, power and transmitter-studio locations. FM Broadcasters, Inc., 711 Colorado Bldg., Washington, D. C.

Phenol and Vulcanized Fibre. Data and information for the correct specification of this manufacturer's phenol and vulcanized Fibre is contained in a 6-page leaflet. N. S. Baer Co., 9–11 Montgomery St., Hillside, N. J.

Plastics. A booklet called "Precision-Made Plastics" describes and illustrates the many types of prastics products which have been fabricated to close tolerances by The Sillcocks-Miller Co., South Orange, N. J.

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Luxtron* Photo-Electric Cells Operate Instruments and Instrument Relays Without Auxiliary Voltage or Amplification.

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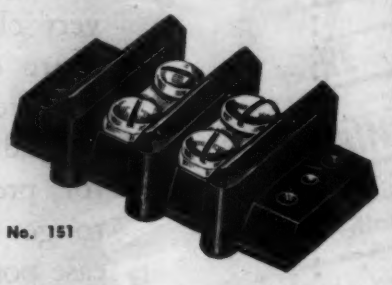
BARRIER STRIPS
SOLVE MOST TERMINAL PROBLEMS



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A compact, sturdy terminal strip with Bakelite Barriers that provide maximum metal to metal spacing and prevent direct shorts from frayed wires at terminals.

6 SIZES

cover every requirement. From ¾" wide and 13/32" high with 5-40 screws to 2½" wide and 1⅛" high with ¼"-28 screws.

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Input Transformers

Designed to occupy minimum space with excellent frequency response, the 400 Series Input Transformers are intended for high quality amplifier requirements. Combines high permeability shield with rotatable strap mounting for minimum stray field pick-up. Equipped with 10" Surprenant color-coded leads. 2" center to center mounting, 1½" O.D. x 2¼" high. Baked gray enamel finish. Available for immediate delivery.

TYPE 400-C BRIDGING INPUT TRANSFORMER

Nominal impedance 600/15,000 ohms to 60,000 ohm secondary. With proper input circuits, input impedance range 0/25,000 ohms. Maximum operating level +10 V.U. at .001 milliwatt reference level.

TYPE 401-A INPUT TRANSFORMER

30/250/600 ohms to 30,000 ohm secondary center tapped. Maximum operating level +10 V.U. at .001 milliwatt reference level.

TYPE 402-A INPUT TRANSFORMER

Nominal 30/120 ohm primary to 50,000 ohm secondary. Input impedance range 0/250 ohms. Maximum operating level +10 V.U. at .001 milliwatt reference level.

Frequency response characteristics as usually expressed for input transformers of wide frequency response are not complete due to variables in circuit constants. Therefore we have prepared an engineering bulletin illustrating exact operating measurements, which is available upon request.

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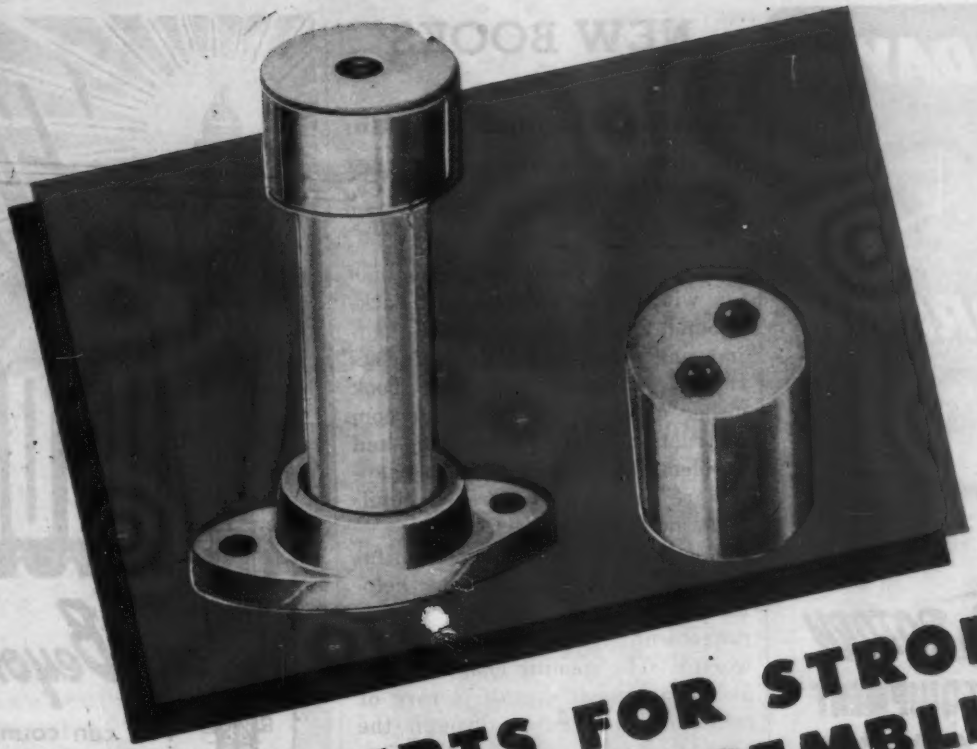
Fungus Proofing Booklet. "Fungus Proofing for the Electronics Industry" is the name of a booklet which tells about this manufacturer's types (25-A, 25-X, 200-T, 95-T, 85-T) of fungus-proofing materials. A page is devoted to a discussion of fungus prevention facts. Also available is a reprint of an article "Fungus Proofing Procedure" which appeared in June 1944 issue of ELECTRONICS. The Insl-X Co., Inc., 855 Meeker Ave., Brooklyn, 22, N. Y.

Western Electric Publication. Western Electric's publication published before the war is now being published again under the new name of The Western Electric Oscillator. The first issue of this new publication contains several articles on radio in the war. There is also a spread of pictures devoted to "75 Years of Pioneering by Western Electric." Another editorial is an article on "AT & T Plans for Television." Western Electric Co., 195 Broadway, New York, N. Y.

Radio Transmitters. Two separate 12-page booklets on radio transmitters are available. The first booklet tells about a 10-kw, low frequency transmitter (designated as Model LF) which is crystal-controlled and designed for point-to-point communication circuits. The second booklet illustrates and describes a 50-kw standard broadcast radio transmitter (designated as Type 162) which is designed for metropolitan broadcasting stations. Federal Telephone & Radio Corp., Newark, N. J.

Electronic Heating. A new job service specializing in electronic heat treating is the subject of a 6-page, illustrated folder. The folder points up the fact that this company's electronic heat treating department is available to industry as a new shop service. Central Boiler & Mfg. Co., 5818 Rivard St., Detroit 11, Mich.

Electrical Test Equipment. Instruments available for production testing are illustrated and described in a 16-page catalog (No. 10). Industrial Instruments, Inc., 17 Pollock Ave., Jersey City 5, N. J.



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NEW BOOKS

Electrical Essentials of Radio

By MORRIS SLURZBERG AND WILLIAM OSTERHELD, *McGraw-Hill Book Co., 330 W. 42ND ST., NEW YORK 18, 530 pages, price $4.*

STUDENTS, as young as high school age with limited mathematical background, can obtain an understanding and solid foundation of electrical principles from this book either at home or with classroom instruction. The questions and problems at the end of each chapter are designed to increase familiarity with the subject.

The material is covered in an interesting manner with many helpful illustrations. Its orderly arrangement is particularly noteworthy. The opening chapter gives an inspirational overall picture of communication down through the ages, finally bringing out the importance of a knowledge of electricity for present communication methods. This is followed by a chapter on the fundamentals of electricity, then by chapters dealing

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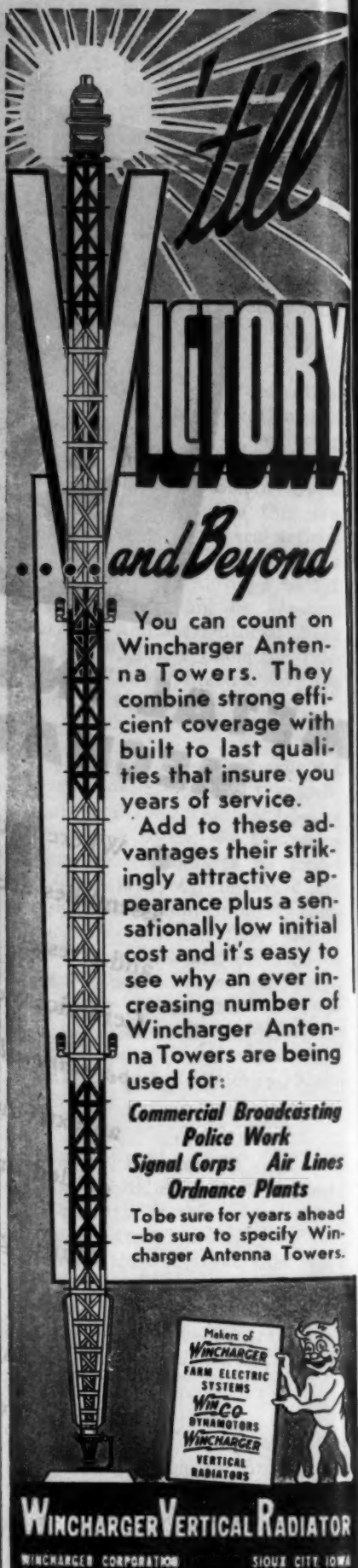

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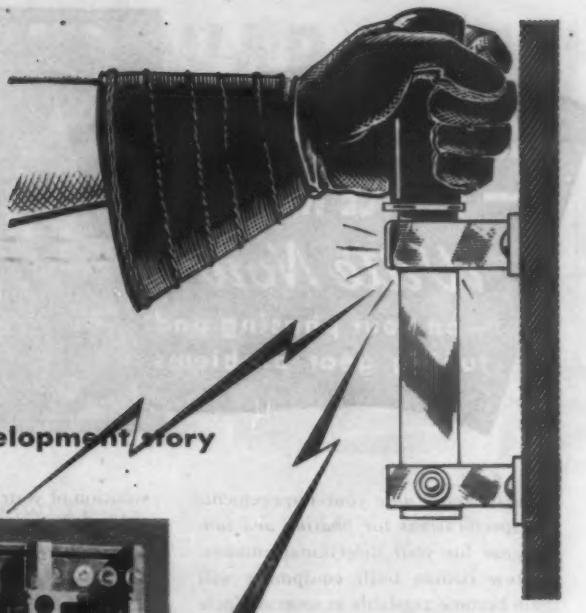
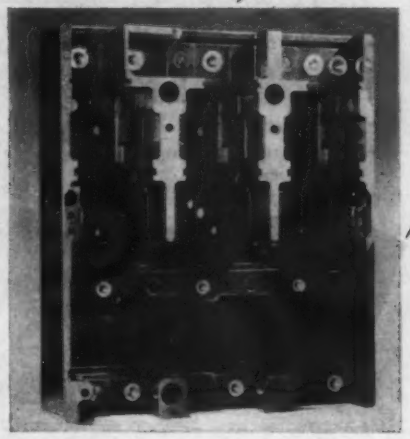
THE TRUMBULL TYPE ATA CIRCUIT BREAKER

. . . another interesting plastic development story





To the designer and manufacturer of electrical products this plastic development story should prove of unusual interest because it is indicative of the tremendous progress which the electrical manufacturing industry is making through the intelligent application of plastics.

TO fulfill the need for devices which could stand temporary overloads and which could be put immediately back into operation, reclosing the circuit without replacing any parts, the Trumbull Electric Manufacturing Company has produced a line of circuit breakers for light and power distribution boards, switchboards, and various types of industrial control.

The development of the ATA Circuit Breakers for Trumbull, as is the case in the successful development of all plastics products, centered around (1) the product designer, (2) the custom molder, and (3) the manufacturer of plastic molding compounds.

In this particular instance, the problem faced was unusually difficult because of the complex nature of the construction and the stringent requirements for electrical resistance and ruggedness in the material used.

As the first basic step, a mold design was worked out, so ingenious that the circuit breaker case comes from its mold (compression molded by the Watertown Manufacturing Company) as a finished product, smooth and ready for assembly of internal mechanisms. Metal inserts, holes, sections, ribs, and cut-outs are *molded-in*, simplifying construction to an amazing degree.

Next came the careful selection of a plastic molding compound. For this purpose, a Durez phenolic compound was chosen because, in addition to possessing exceptional electrical properties, its versatility extended to other needed qualities such as impact strength, moisture resistance and moldability. *A plastic that fits the job*

The unusual versatility of the more than 300 Durez phenolic molding compounds has made their use practically universal throughout industry. As a result of this usage Durez laboratory technicians have gained a wealth of experience which embraces practically every field of endeavor.

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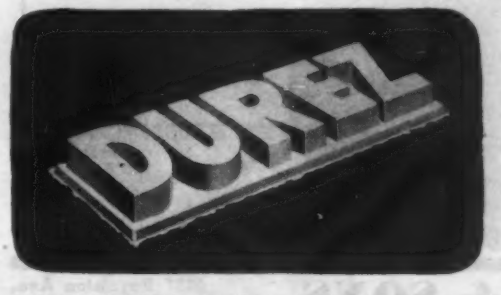
You may be assured of the utmost cooperation of the Durez staff, at any time, in helping your product designer and custom molder work out any materials problem which you may have. Durez Plastics & Chemicals, Inc., 811 Walck Road, North Tonawanda, N.Y.



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PLASTICS THAT FIT THE JOB

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Write Now!
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• Let us know *now* your requirements and specifications for *phasing and tuning gear* for your directional antenna. Andrew custom built equipment will again become available as soon as Uncle Sam releases our engineering and manufacturing facilities from production for war.

This release may come at any moment. Be sure that your needs are listed at the top of our peace-time back-log. The planning you do now will speed your own reconversion to the new high standards of the future.

Andrew engineers will gladly apply their years of skilled experience to the solution of your special problems in the field of directional antenna equipment:

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- Antenna tuning units
- Remote reading antenna ammeters
- Phase monitors
- Coaxial transmission lines and accessories

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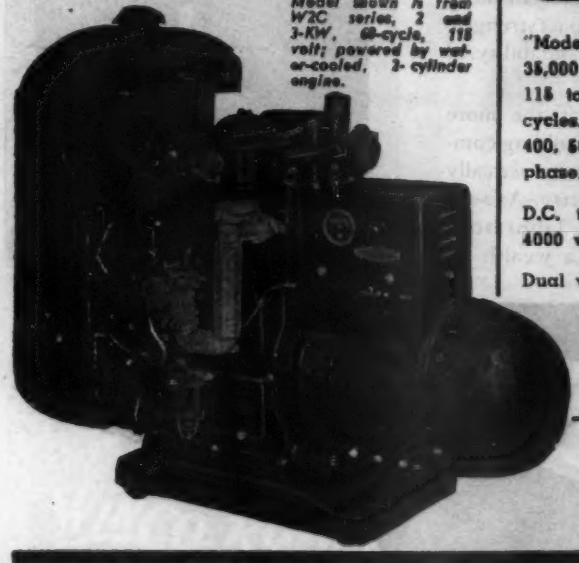

Model shown is from W2C series, 2 and 3-KW, 60-cycle, 115 volt; powered by water-cooled, 2-cylinder engine.

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with particular phases of electricity: batteries, electric circuits and their computation, and magnetism. Two chapters describe electrical instruments and their operation, and the application of electricity in motors, generators and transformers. In preparation for the final chapter on basic radio circuits and resonance, the book devotes three chapters to inductance, capacitance, and alternating current circuits. It should be emphasized that this book adheres rigidly to the scope implied by its title, and hence no complete practical radio circuits are given. Miscellaneous information and tables are given in a 32-page appendix.—M.G.V.

• • •

Communication Circuits

By L. A. WARE and H. R. REED, *State University of Iowa. John Wiley and Sons, New York, 2nd ed., 1944, 330 pages, price $3.50.*

TO THOSE WHOSE primary interest is in filters, transmission lines, four terminal networks, and wave guides, this book should fill the requirements for an analytical treatment of these topics. It is written to serve as first-course material for those interested in communication engineering, but a knowledge of Maxwell's equations and Bessel functions is necessary for an understanding of all parts of the text.

The subject matter is divided into the following broad topics: networks, transmission lines, filters, impedance transformation, and wave guides. One chapter is devoted to transmission line experiments, and there are nine appendices of mathematical character. Throughout, emphasis has been placed on the concepts at extremely high frequencies.

Three chapters on wave guides constitute the largest section devoted to a single topic. The first chapter lays the general groundwork and physical interpretation of wave guides in general. The remaining chapters deal, respectively, with rectangular and cylindrical wave guides.

Chapter XV outlines the electromagnetic theory of coaxial lines. In Chapter XVI will be found a brief outline of a dozen experiments which may be made on wave guides and transmission lines. Problems are provided.

Since the volume emphasizes

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Based on Mutual Experience

Two kinds of experience went into the formulation of our postwar plan.

1 **Our Customers' Experience** with our wartime services. So far as we can determine, it has been thoroughly satisfactory. Our prewar customers called upon us for stepped-up quality and quantity in communication and electronic specialties for wartime. We met that demand promptly.

Many new customers who, before the war, manufactured all parts of their equipment, placed their problems in our hands. We believe that their experience will point to the continued use of our facilities after Victory.

2 **Our Own Experience** with wartime production has been tremendous. No one can say whether the past three years have been worth six, twelve or twenty years of normal peacetime experience. But the fact is clear that it has helped us develop production "muscles" that enable us to carry greater loads than ever before.

So, based upon our customers' and our own experiences, we have a very simple postwar plan. It is to continue to serve our host of customers with our facilities, skills and experience in producing equipment to meet their specialized needs for performance, quality, quantity and low cost. We are confident that our customers' wartime experiences assure us a sound future.

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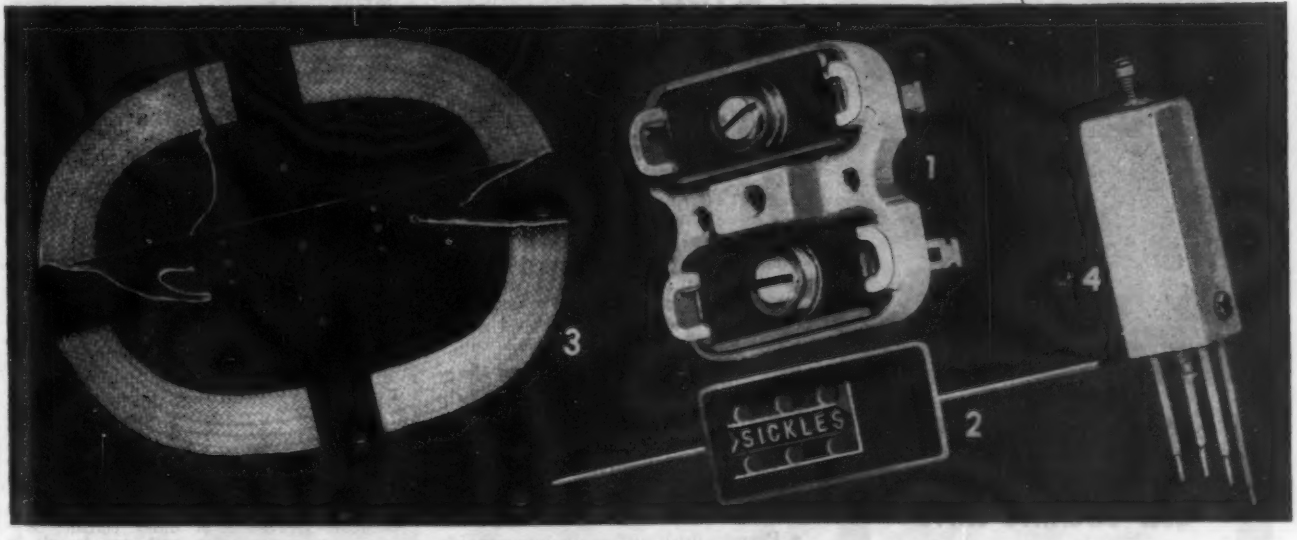

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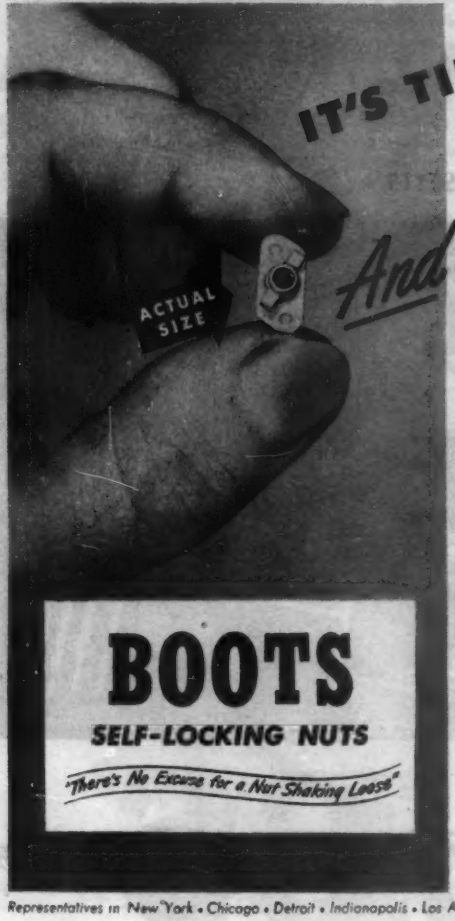

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u-h-f techniques and principles, it should be a welcome addition to the library of anyone working in that field. However, the omission of any treatment of vacuum tubes and of lumped circuits precludes it from serving all engineering needs of the communication engineer.—B.D.

• • •

Shop Job Sheets in Radio Book II—Service Problems

BY ROBERT N. AUBLE, *The Macmillan Co., New York, 1944, 128 pages, 11x8¼ in., paper covers punched for standard binder, price $1.50.*

TWENTY-FIVE JOB SHEETS are provided, similar in format and designed as a follow-up to the radio fundamentals covered in Book I (reviewed in August 1944 ELECTRONICS). The first five job sheets cover testing radio resistors, condensers, transformers, filter chokes, and vacuum tubes. The next three are lessons in the construction of a power supply, a high-gain audio amplifier stage, and a power amplifier with phase inverter driver. One job is an overall test of an audio amplifier. There are nine jobs dealing with the superheterodyne receiver. The last seven of the job sheets deal with transmitters and cover the Hartley oscillator, electron-coupled oscillator, quartz-crystal oscillator, radio - frequency amplifiers, frequency-doubler circuits, the power supply, and modulation.—J.K.

• • •

Books Received for Review

MAINTENANCE AND SERVICING OF ELECTRICAL INSTRUMENTS. By James Spencer; edited by Major M. F. Behar, editor of *Instruments*. The Instruments Publishing Co., Inc., Pittsburgh, 1944, 256 pages, $2.00. Reprint of serialized articles published since Aug. 1941 in *Instruments* magazine; practical and well illustrated.

METHODS OF ADVANCED CALCULUS. By Philip Franklin. McGraw-Hill Book Co., Inc., New York 18, 1944, 486 pages, $4.50. Arranged for use as college text, but suitable for reference or self-study by practicing engineers. Covers partial derivatives of implicit functions and Jacobians, vector notation, Fourier analysis, calculus of variations, Bessel functions and related topics.

TECHNIC OF ELECTROTHERAPY. By S. L. Osborne and H. J. Holmquest. Charles C. Thomas, Publisher, Springfield, Ill., 1944, 780 pages, $7.50. Medical electronics and electricity, presented essentially as taught to classes for physicians, medical students and technicians at Northwestern University Medical School. Divided into four major sections: Effects and technical application of direct current; electrical muscle stimulation, with new technic for stimulating vocal cords; radiation—physics and application, both heat-producing and ultraviolet; high-frequency currents, occupying over half the book and covering circuit theory, generation, general diathermy applications and surgical diathermy including electrodessication, electrocoagulation and electrocutting.

DIRECT-CURRENT CIRCUITS. By Earle M. Morecock. Harper & Brothers, New York

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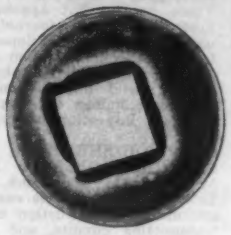
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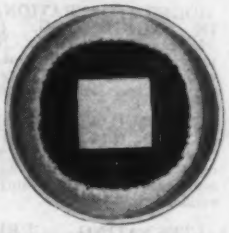
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Our armed forces fight on many fronts in this global war, but in some, notably in Burma and the South Pacific, they must often face another insidious foe—the ever-present mold and fungus growths that impair the successful operation of radio, electronic and electrical equipment.

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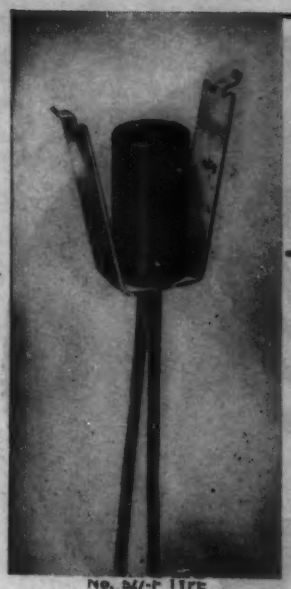

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18, 1944, 387 pages, $3.25. For use in technical institutes, junior colleges, industrial and extension schools. Questions, problems, lab experiments. Elementary circuits, magnetism, instruments and measurements, power, conductors, batteries, Kirchhoff's laws, magnetic circuits, d-c motors and generators, capacitors and electrostatic fields.

THERMIONIC VALVE CIRCUITS. By Emrys Williams. Sir Isaac Pitman & Sons, Ltd., London, 1944, 207 pages, 12s. 6d. Second Edition. Theory of operation and design of thermionic tube circuits, primarily for third-year electrical engineering students, with new material in this edition on f-m circuits, gaseous tubes, time bases, multivibrators, cathode followers and v-t voltmeters.

MARINE RADIO MANUAL. Edited by M. H. Strickartz. Cornell Maritime Press, New York 11, 1944, 518 pages, $4.00. One-volume guide for beginners, students and experienced radio operators, covering operation, maintenance, repair, laws, regulations, radio navigation, code, signals, calls, auto-alarms, bookkeeping, sample messages, radio medical aid.

INTERNATIONAL TELECOMMUNICATIONS. By Osborne Mance. Oxford University Press, New York 11, 1944, 90 pages, paper cover, $1.00. Discussion of problems of last 20 years, with suggestions for handling some of the present unsolved international communications problems.

RADIO—FUNDAMENTAL PRINCIPLES AND PRACTICES. By F. E. Almstead, K. E. Davis and G. K. Stone. McGraw-Hill Book Co., Inc., New York 18, 1944, 219 pages, $1.80. Foundation training, for high-school classes, evening classes for adults, and Armed Forces schools.

MEET THE ELECTRON. By David Grimes. Pitman Publishing Corp., New York 19, 1944, 120 pages, $2.00. The story of 20 years of electronics, interestingly presented for non-technical readers. Based on lectures given before the author's fatal airplane crash in Ireland.

SAMPLING INSPECTION TABLES. By H. F. Dodge and H. G. Romig. John Wiley & Sons, Inc., New York 16, 1944, 106 pages, $1.50. Three papers that appeared originally in *Bell System Technical Journal*, describing sampling inspection tables developed for use in manufacture of communication apparatus and equipment for the Bell Telephone System, reprinted with a brief introduction covering advantages and shortcomings of sampling as contrasted to complete inspection of production output.

SHOP JOB SHEETS IN RADIO; BOOK II—SERVICE PROBLEMS. By R. N. Auble. The Macmillan Co., New York, 1944, 128 pages, $1.50. Twenty-five job sheets covering testing of radio components, construction of basic receiving and transmitting circuits, and circuit experiments.

MODERN OPERATIONAL MATHEMATICS IN ENGINEERING. By R. C. Churchill. McGraw-Hill Book Co., New York 18, 1944, 306 pages, $3.50. Solution of differential equations of engineering and physics by Laplace transformations and other methods.

THE LIQUIDATION OF WAR PRODUCTION. By A. D. H. Kaplan. McGraw-Hill Book Co., New York 18, 1944, 133 pages, $1.50. Recommendations of an economist for contract cancellations, disposal of surpluses and plant conversions.

ALTERNATING CURRENT BRIDGE METHODS. By B. Hague. Isaac Pitman & Sons, New York, 1943, 616 pages, $8.50. Fifth edition, with minor changes and addition of material on copper-oxide and cathode-ray detectors and an appendix on bridge circuits.

MATHEMATICAL AND PHYSICAL PRINCIPLES OF ENGINEERING ANALYSIS. By W. C. Johnson, McGraw-Hill Book Co., New York 18, 1944, 345 pages, $3.00. Essential physical and mathematical principles needed for analysis of practical engineering problems, with emphasis on methods of attack, setting up equations and interpreting results.

AIRCRAFT INSTRUMENTS. By G. E. Irvin. McGraw-Hill Book Co., New York 18, 1944, 607 pages, $5.00. Second edition, with new material on many newly developed electrical aircraft instruments.

SPEAK WELL—AND WIN. By W. P. Sanford. Whittlesey House, New York 18, 1944, 176 pages, $2.00. Practical advice on speaking convincingly and clearly, for those who must present technical problems to the public.

AIRCRAFT PRODUCTION ILLUSTRATION. By G. Tharratt. McGraw-Hill Book Co., New York 18, 1944, 201 pages, $2.75. Presentation of the various illustrative techniques available to all industrial drafting departments, with aircraft problems serving as examples.

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And to top it off, it had to be "lighter than anything on the market," *they said. What, we asked, was it for? They couldn't tell us, and we don't know to this day, but we do know it was badly needed.

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Backtalk

This department is operated as an open forum where our readers may discuss problems of the electronic industry or comment on articles which ELECTRONICS has published.

On Frequency Recommendations

Dear Sirs:

I AM MOST UNPLEASANTLY surprised to notice in your August report on the plans of the television committee of the RTPB for frequency allocation that you have not brought it to the attention of your readers that the 50-56 Mc channel is disputed territory. As you probably know, Frequency Modulation Broadcasters, Inc. has proposed that this band be allocated to frequency modulation. You state, "Since the report

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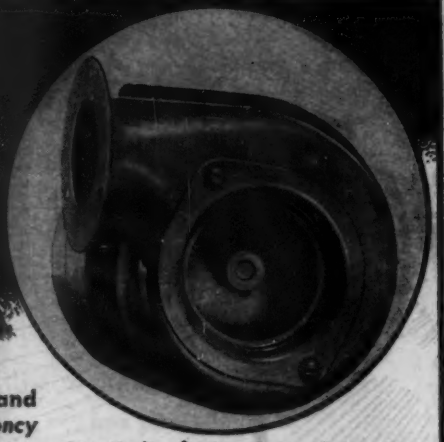

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represents the unanimous opinion of the leading technical figures in the television field, it is believed that the recommendation will be adopted without major changes." It seems to me that this is not a fair scientific discussion of what is a most important issue.

In view of the unpleasant history of frequency modulation politics, it would seem highly desirable for ELECTRONICS to invite qualified persons representing both sides of the question to state their positions in your columns. If this is not done ELECTRONICS lays itself open to the charge of supporting a certain group without even mentioning that the stand of this group is in dispute.

The Committee's report gives promise of a widely expanded television service after the war. This is certainly desirable. On the other hand, it is also important to make sure that the parallel development of fm be considered as part of the total problem of expanding postwar radio facilities. The allocation of frequencies is such an important aspect of this that an opportunity

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should be given for the fullest discussion of the issue.

L. B. ARGUIMBAU
Assistant Professor
Massachusetts Institute of Technology
Cambridge, Mass.

See RTPB on FM, in this issue. Statements of position and other comments are most welcome. (Ed.)

• • •

Polarized Speech

Dear Sirs:

MR. LEE CLOUGH'S letter in Backtalk of the April 1944 issue of ELECTRONICS inquired about subject matter relating to polarized speech and commented on the lack of information on this subject in current manuals and texts. . . . .

Information on this subject can be found in an article by Mr. J. L. Hathaway in the October 1939 issue of ELECTRONICS, dealing with the effect of microphone polarity upon modulation percentage.

It may also be possible Mr. Clough has reversed leads in some studio or line amplifier input circuit. An article in December 1939 issue of *Radio*, dealing with extended positive peak modulation, points out how this condition may

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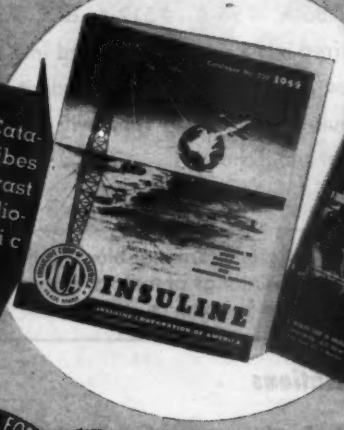

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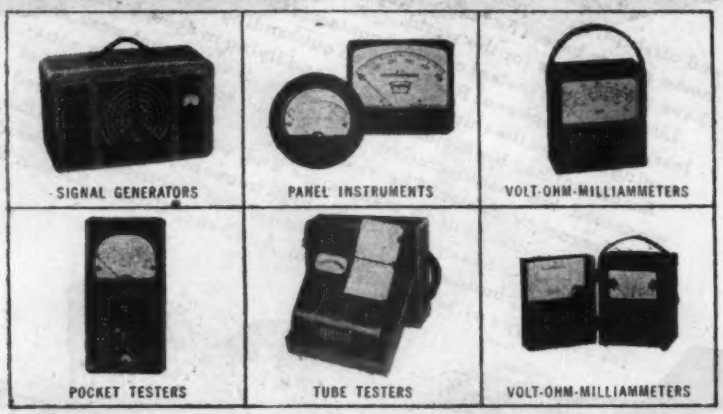

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be realized by reversal of input circuit leads in speech equipment, its effect on modulator output waveform, and the carrier modulation envelope.

I hope the articles referred to will assist Mr. Clough in his persual of this subject.

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• • •

Paint at Work

Gentlemen:

IN REFERENCE to the excellent suggestions contained in Rackey's Small Tube Conservation article (April 1944) I would like to add that over a period of years I have found that after painting the glass envelopes of receiver-type power tubes and other tubes critical as to grid emission with a heat-resistant dull-gloss black paint, and allowing the paint to dry thoroughly before using, the emission characteristics of such treated tubes held up re-

LEGAL NOTICE

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC., REQUIRED BY THE ACTS OF CONGRESS OF AUGUST 24, 1912, AND MARCH 3, 1933

Of Electronics, published Monthly at Albany, New York, for October 1, 1944.

State of New York } ss.
County of New York }

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Joseph A. Gerardi, who, having been duly sworn according to law, deposes and says that he is the Secretary of the McGraw-Hill Publishing Company, Inc., publishers of Electronics, and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management, etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, to wit:

1. That the name and address of the publisher, editor, managing editor, and business managers is: Publisher, McGraw-Hill Publishing Company, Inc.; Editor, Keith Henney; Managing Editor, W. W. MacDonald; Business Manager, Wallace B. Blood; all of 330 West 42nd St., New York City 18.

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markably well as contrasted with similar unpainted tubes.

Perhaps this is attributable to the fact that a black body radiates heat more effectively, thus permitting the internal elements of such tubes to operate at a lower temperature.

PHILIP ROSS
Staff Engineer, WBN
New York, N. Y.

• • •

A Correction

Dear Mr. Henney:

RECENTLY I have belatedly been going over an interesting article in the July 1943 issue of ELECTRONICS, Transmission Line Charts, by R. F. Baum. One point puzzled me until I became convinced it must be an error.

At the top of page 158 is the statement, "going along the line $X'Z'$ in Chart I we have for the point X', the value $T = 0.58$ and $\theta = 157$ deg. X' is previously given as, $-33 + j10.6$ on page 94 and it corresponds to approx. $T = 0.64$, $\theta = 157$, on Chart I, which I believe to be the correct value. The value given as $T = 0.58$, appears to correspond to X' on Chart II instead

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of Chart I. The value of I as found in the last paragraph would also be affected if the value of T above is in error.

It is interesting to note that Chart I for tan $(a + jb)$ is used to solve the same kind of problems as a chart for tanh $(\sigma + j\tau)$ by Paul J. Selgin in *Communications* for Feb. 1944. These two functions are of course related by the equation, $j \tan (a + jb) = \tanh j (a + jb)$.

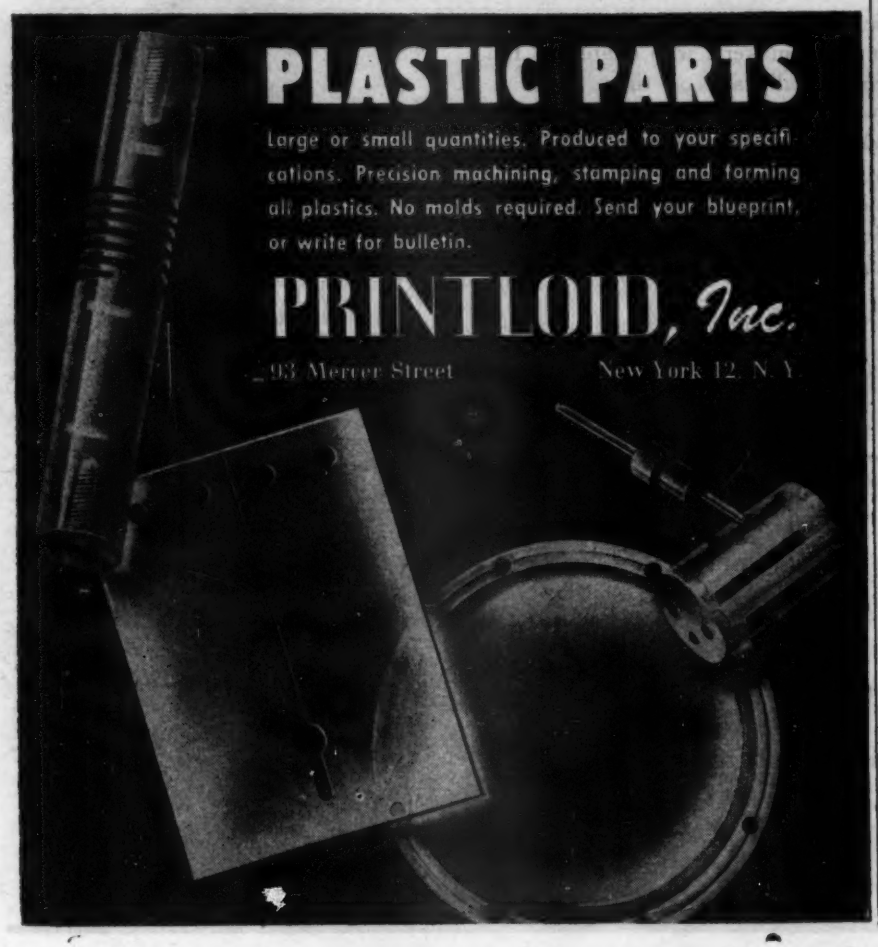
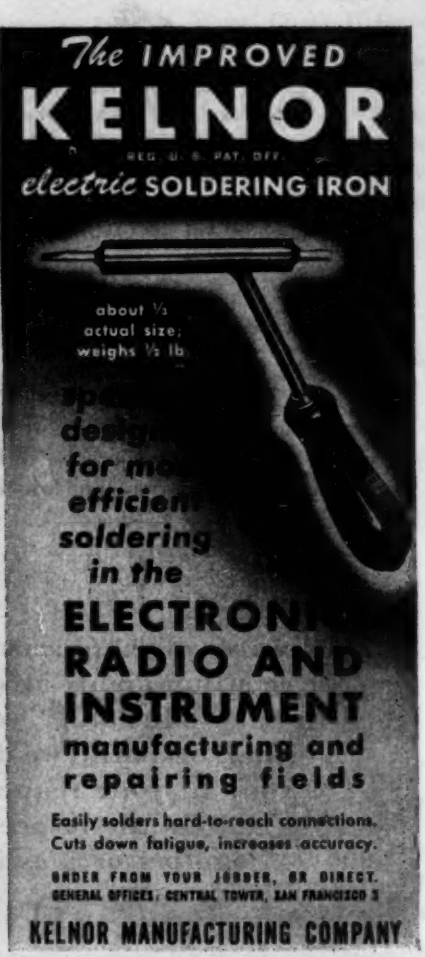
ROBERT C. PAINE
Boonton, N. J.

Dear Mr. Paine:

. . . . . I rechecked the article in question. The value for T should be 0.64, as you state, and not 0.58. Thank you very much for bringing this error to my attention. The value of I had to be changed accordingly.

I was not able to obtain Mr. Selgin's article. The tan $(a + jb)$ and the tanh $(\sigma + j\tau)$ charts should be identical but for the direction of the coordinate axes and an angle of 90 deg.

R. F. BAUM
Industrial Instruments Inc.
Jersey City, N. J.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